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Directorate of Combat Operations Analysis
US Army Combined Arms Combat Developments Activity
Fort Leavenworth, Kansas 66027

TANKS VERSUS INFANTRY

IN A SMOKE ENVIRONMENT

(TISE)

by

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This paper contains an analysis of the data collected during the Tanks versus Infantry in a Smoke Environment (TISE) field experiment. The test was conducted at Fort Hunter Liggett, California during August 1977. The purpose of TISE was to provide data on the effects of a smoke environment on the performance of infantry armed with LAWs in the defense and armor crews in the attack. Trials were conducted with single and multiple armor targets, moving and stationary armor and infantry, and firing and nonfiring armor and infantry. Fog oil smoke was placed over the playing area prior to conduct of trials by land-mobile generators.

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20. with generators mounted on helicopters for backup. All target detections and recognitions were strictly visual. Results include times to target detection, recognition, and engagement; range, both actual and estimated, of targets at recognition; and the number of correct versus incorrect recognitions. Analysis was performed to determine any significant effect of the independent variables on the results.

ABSTRACT

This paper contains an analysis of the data collected during the Tanks Versus Infantry in a Smoke Environment (TISE) field experiment. The test was conducted at Fort Hunter Liggett, California during August 1977. The purpose of TISE was to provide data on the effects of a smoke environment on the performance of infantry armed with LAWs in the defense and armor crews in the attack. Trials were conducted with single and multiple armor targets, moving and stationary armor and infantry, and firing and nonfiring armor and infantry. Fog oil smoke was placed over the playing area prior to conduct of trials by land-mobile generators, with generators mounted on helicopters for backup. All target detections and recognitions were strictly visual. Results include times to target detection, recognition, and engagement; range, both actual and estimated, of targets at recognition; and the number of correct versus incorrect recognitions. Analysis was performed to determine any significant effect of the independent variables on the results.

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1. INTRODUCTION. The purpose of this report is to present the results of the Combat Operations Analysis Directorate's analysis on the data collected during the Tanks versus Infantry in a Smoke Environment (TISE, ACN 23137) experiment. The Combined Arms Combat Developments Activity (CACDA) at Fort Leavenworth, Kansas and the TRADOC Systems Analysis Activity (TRASANA) at White Sands Missile Range, New Mexico were joint proponents for the test. The Combat Developments Experimentation Command (CDEC) located at Fort Ord, California was designated as the testing agency for TISE, which was conducted during August 1977 at Fort Hunter Liggett, California.

2. PURPOSE. The TISE experiment was designed to provide data on the effects of a smoke environment on the performance of infantry armed with lightweight antiarmor weapons (LAWs) in the defense and of armor crews in the attack. The LAW provides the potential for every soldier to be a tank killer. Currently it is the only infantry weapon that can engage tanks at ranges less than 65 meters. For the rifle squad and other elements of the Army not having antitank weapons organic to their units, it provides a primary means of antitank protection in both defensive and offensive situations. In limited visibility conditions such as those caused by the employment of smoke, it becomes an increasingly important means of protection. Five main objectives were developed for the TISE experiment. Of the five listed below, only objectives 1 and 2 are addressed in this report. The USACDEC final report discusses the others (USACDEC, Tanks versus Infantry in a Smoke Environment (TISE), FC 070, December 1977).

- Objective 1: To collect data on the ability of LAW armed infantry to detect, recognize, and engage attacking armor vehicles in a smoke environment.

- Objective 2: To collect data on the ability of armor crews to detect, acquire, and engage infantry in defensive postures in a smoke environment.

- Objective 3: To collect subjective data on the problems infantry personnel and vehicle crews have when maneuvering in smoke.

- Objective 4: To collect subjective data on the problems the infantry squad leader and armor force commander have when coordinating the employment of their units' weapon systems in a smoke environment.

- Objective 5: To collect data which can be used to evaluate selected aspects of the LAW and armor training programs.

3. SCOPE AND LIMITATIONS. The test was divided into four parts. Part I, Phases 1 and 2, had single or multiple vehicles approaching along specified lanes toward the infantry force emplaced along either the left or right flank or the front of the playing area. Trials were conducted with and without simulator firing cues by the armor force. Data were collected only from the infantry players. In Part II, the five-vehicle armor force, in both buttoned and unbuttoned modes, approached infantry who were emplaced along the front

and both flanks of the playing area in three varying postures. The infantry were armed with LAW simulators and provided firing cues during half the trials. Data were collected from both the armor crews and infantry. Part III had an infantry squad maneuvering toward stationary armor vehicles in an attempt to detect and recognize them. Finally, Part IV trials were limited free-play, two-sided engagement exercises with data collected from both sides. All infantry players wore the standard issue gas mask during trials; armor crews did not. Detections were strictly visual, with no optical equipment being used. Smoke was produced to cover the entire playing area prior to conduct of any trial. Only fog oil was used. Smoke was emplaced by land mobile generators (M3A3) and, when necessary, by helicopter (UH-1H equipped with an M52 smoke system). TISE was the first large scale smoke experiment conducted by CDEC. It was not known if smoke could be reasonably controlled for extended periods of time over a large area; therefore, instrumented readings of smoke density were not taken. Rather, a series of panels were placed at given intervals both across and down the playing areas. Photos were taken of these panels at 10 to 15 second intervals during each trial to record a rough measure of how far one could see into the smoke. Due to safety considerations, armor crews were restricted to maneuvering within specified travel lanes marked on the playing area.

4. TEST DESCRIPTION.

a. Scenario. An infantry squad leader anticipates a heavy tank attack, identifies a likely avenue of approach, and positions his fire teams to cover it. Supporting antitank firing positions have been selected to provide massed fires along the expected armor avenue of approach. Defense artillery has been employed (assumed in half of the trials) to force the attacking elements to button up.

b. Site Description. Figure 1 is a schematic of the general site layout. Three different areas were used in TISE. Continuous line of sight (LOS) existed from the defensive area to the threat assembly area in the two sites used for parts I, II, and III trials. The final site used for part IV trials was chosen for tactical reasons and did not have continuous LOS from every infantry position. The threat area of approach was approximately 200 meters wide and 500 meters long. Each armor vehicle lane (average 40 meters in width) was marked on the ground by white tape. These markings were removed for part IV free-play trials. A total of 32 defensive positions at each site were marked along the front and both flanks of the approach area. These included foxholes and open and hasty defensive positions. Markers were randomly placed behind the defensive area to aid in verification of armor crew detections. Numbered panels (10) were placed down the center lane at 30-meter intervals from the defense area back toward the threat assembly area. A camera was emplaced so that the entire line of panels could be photographed during each trial. This same concept to aid in measuring the smoke density was also employed across the center of the trail area.

c. **Test Description.**

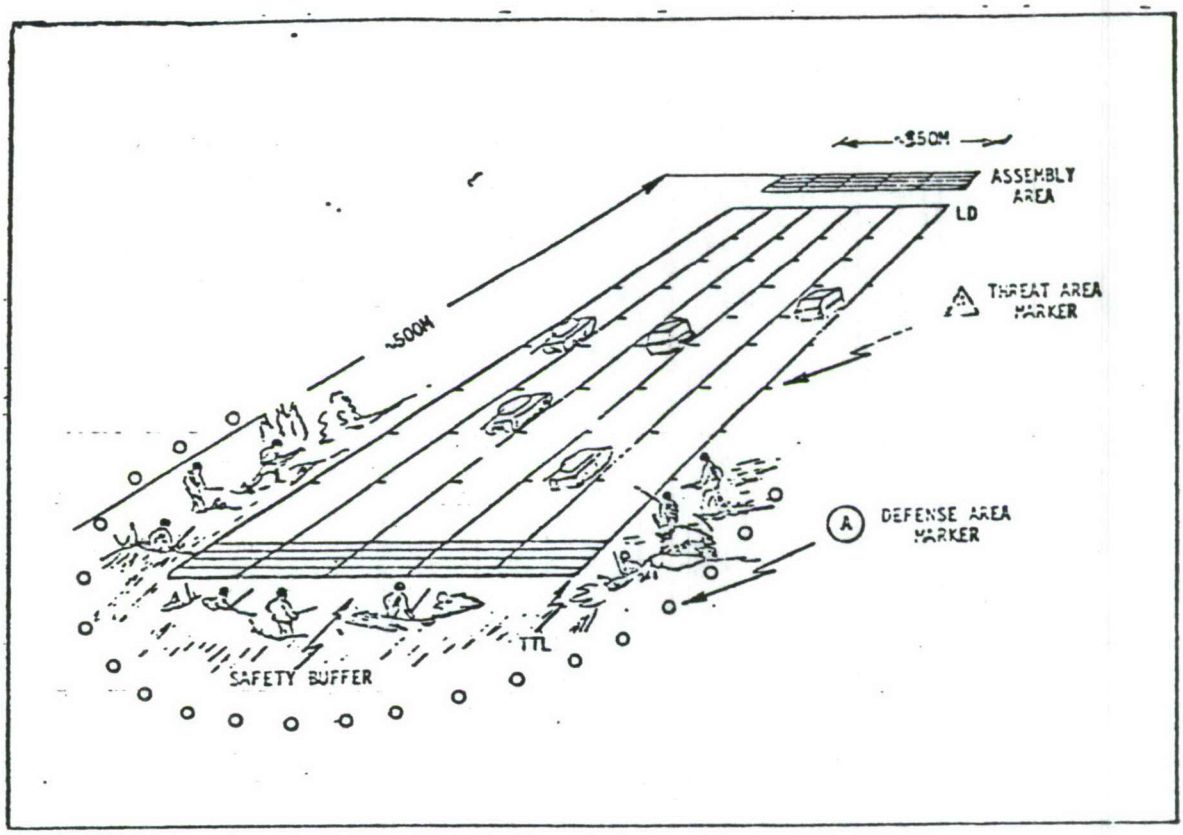

Figure 1. Site layout

(1) Part I collected data on the ability of infantry occupying open observation positions to visually detect and recognize closing armor vehicles. Phase 1 of Part I had a single vehicle, either an M60A1 tank or an APC, approach the defensive area in one of the five defined lanes. In Phase 2 five vehicles (three tanks and two APCs) came forward in an on-line or wedge formation with one vehicle in each lane. The lane varied for each element in every trial. Two squads of infantry were deployed along the front and both flanks of the approach area. Three postures (sitting, standing, or prone) were used. Every infantry player wore the standard issue gas mask. An equal number of trials were conducted in both phases in which the armor crews fired a main simulator to determine if this type of cueing aided the detection process in smoke.

(2) Part II trials collected data on the ability of advancing armor crews to detect and recognize infantry in defensive positions. The armor force of five vehicles used only an on-line formation in both buttoned and unbuttoned postures. All four crew members were able to report detections. Data was also taken from the infantry players as in part I. In addition, LAW simulators were fired to determine if this provided a significant cueing effect to the armor crews.

(3) For Part III trials the five armor vehicles occupied stationary positions near the assembly area with engines turned off. A single infantry squad maneuvered on foot toward the armor force and attempted to detect and recognize them. Data were collected from both sides.

(4) Part IV was free-play, force-on-force engagement trials. Defensive positions were tactically chosen by the infantry squad leader, while the armor force commander was able to develop his own plan of attack. Players and weapons were deployed in as realistic a manner as possible.

d. Data Collection.

(1) The hit and kill potential of the LAW is affected by target distance, speed, and attack angle. Considering these factors, the following seven independent variables were tested:

- infantry squad area of defense
  - front
  - flank
- infantry posture
  - prone/hasty defense
  - standing/open
  - foxhole
- infantry and armor weapon cueing
  - firing/nonfiring

- armor tactical formation
  - line
  - wedge
- type armor vehicle
  - tank (M60A1)
  - APC (M113)
- armor force size
  - single vehicle
  - multiple vehicles (5)

(2) The design matrices in figures 2 through 5 show the various independent variable combinations that were investigated in TISE. The total number of trials executed are found in each cell of the matrix. The data that were collected from the infantry and armor players included:

- time of target detection
- time of target recognition
- time of trigger pull (engagement)
- time of target obscuration
- player estimate of and actual target range at time of recognition
- player estimate of and actual target speed at time of recognition
- player estimate of and actual target aspect
- position location of each moving player

e. Conduct of Trials. Prior to the start of trials smoke was placed over the entire playing area. Six mobile generators (M3A3) along with a helicopter-mounted generator (M52) were used. After the smoke was emplaced the infantry would occupy their designated positions and postures for that trial while the armor crews moved to their preselected lanes of approach. Average visibility ranged from 0 to 100 meters. A data collector was with each defender and armor crew. At the start of each trial the armor vehicles moved along their designated lanes at as constant a speed as possible. When firing cues were required, the tank main gun was used against infantry detected in foxhole and hasty positions and the machine gun (tank and APC) against those perceived to be in the open. When a player first detected a target he verbally relayed this to the data collector who entered it, time-tagging the event, into the computer. Upon recognition of the target, the target type was called out by the player and time recorded by the computer. The players' estimates of target range, speed, and aspect were manually recorded. Trials were ended when all vehicles reached the trial termination line.

5. ANALYSIS METHODOLOGY.

a. Data. Data used in this analysis were provided to USACACDA by USACDEC. They represent CDEC's level 3 data, which is data that have been

		ARMOR FORCE											
		TANK						APC					
		FIRING			NONFIRING			FIRING			NONFIRING		
		LANES			LANES			LANES			LANES		
		1	2	3	1	2	3	1	2	3	1	2	3
INFANTRY	FRONT AND FLANK	1	1	1*									
	FRONT AND FLANK												

* 1 trial per cell, 20 possible observations per trial.

		ARMOR FORCE			
		TACTICAL FORMATION			
		LINE		WEDGE	
		FIRING	NONFIRING	FIRING	NONFIRING
INFANTRY FORCE	FRONT AND FLANK	3	3	3	3
	FRONT AND FLANK	3	3	3	3

Figure 2. Design matrices, part I TISE, phases 1 and 2

		ARMOR FORCE	
		BUTTONED	UNBUTTONED
INFANTRY	FIRING	6	6
	NON-FIRING	6	6

Figure 3. Design matrix, part II TISE

		ARMOR FORCE	
		BUTTONED	UNBUTTONED
INFANTRY	SQUAD 1	6	6
	SQUAD 2	6	6

Figure 4. Design matrix, part III TISE

		ARMOR FORCE	
		BUTTONED	UNBUTTONED
INFANTRY	FIRING	6	6
	NON-FIRING	6	6

Figure 5. Design matrix, part IV TISE

checked for accuracy and placed in logical order. No arithmetic operations are applied to data at this level. The photographic data of the ranging panels taken during each trial were also provided for review. Due to the variations in smoke density that occurred over the playing area as viewed from these still photos and on-site observations, data for this analysis were aggregated over all density levels. The results thus obtained present a more generalized picture of detection ranges, etc., that occur when visual conditions are degraded to an average maximum of 100 meters.

b. Analysis Performed. The results presented in the following paragraph consist of means and standard deviations of times, ranges, and speeds for both infantry and armor players for various factor combinations and percentages of correct and incorrect recognitions. Due to the wide variances in sample sizes and for ease in analysis, nonparametric statistical tests were chosen for determining any significant differences between chosen samples. The Wilcoxen matched pairs signed ranks test was used to detect any difference between the actual range and speeds of targets at recognition and the players' estimates of these two dependent variables. The Kolmogorov-Smirnov test (K-S test) was used to discover significant effects of various independent variables, such as posture, use of firing cues, and vehicle formation, on detection/recognition times and ranges. The K-S test was also used to compare armor and infantry reaction times and range estimates.

6. ANALYSIS RESULTS.

a. General Results. Table 1, and all subsequent tables, presents an overall view of the test results. Data are given by individual test part for infantry and armor players. All times are given in seconds from start of trial. Ranges are in meters from player to target. Speeds are in meters per second. A recognition was considered to be correct if (1) both the recorded data for player estimate of target type and recorded data for actual target type were given as valid data points, and (2) both the player estimate of target type and actual target type were the same. Figures 6 through 21 show the range of recorded values in 10-meter increments and their cumulative distribution curves for each of the columns in table 1 for the estimated and actual target range at time of recognition. All cumulative curves were fit to a log normal distribution whose parameters are listed under the experimental mean and standard deviation. The y-axis in the histogram graph represents the density, while in the cumulative curve graph its values are percentages of the total.

(1) When a Wilcoxen Matched Pairs Signed Ranks test was conducted on these estimated and actual target range/speed values, in each case there was no statistically significant difference between the two (α = .05 level). Although the differences were not statistically different, it is interesting to note that in almost all cases a majority of the estimated values, approximately 64 percent, were less than the actual target range and 65 percent were less than the actual target speed. Table 2 shows the breakdown for the individual parts.

Table 1. Averages overall factors for each part - armor and infantry

	Part I Phase 1 by Infantry	Part I Phase 2 by Infantry	Part II by Infantry	Part II by Armor	Part III by Infantry	Part III by Armor	Part IV by Infantry	Part IV by Armor
time to detection	75 sec	127	94	93	281	299	110	112
Sample size: N	291	881	406	115	857	294	398	107
time to recognition	79 sec	129	97	99	283	310	113	115
Sample size: N	277	894	403	109	848	294	391	106
time to engagement	---	---	216	104	---	312	119	119
Sample size: N			331	105		282	328	101
time from detect to recognition	4 sec	2	3	3	3	12	2	2
time from recognition to engage	--- sec	---	115	4	---	1	7	3
estimated target range	105 meters	82	94	72	77	70	91	67
actual target range	134 meters	97	111	97	89	85	112	79
estimated target speed	2.6 m/sec	2.2	2.2	---	---	---	2.1	---
actual target speed	2.4 m/sec	4.0	3.8	---	---	---	3.4	---
no. correct recognitions	267	773	333	39	819	294	368	49
no. incorrect recognitions	2	18	8	52	14	0	7	45

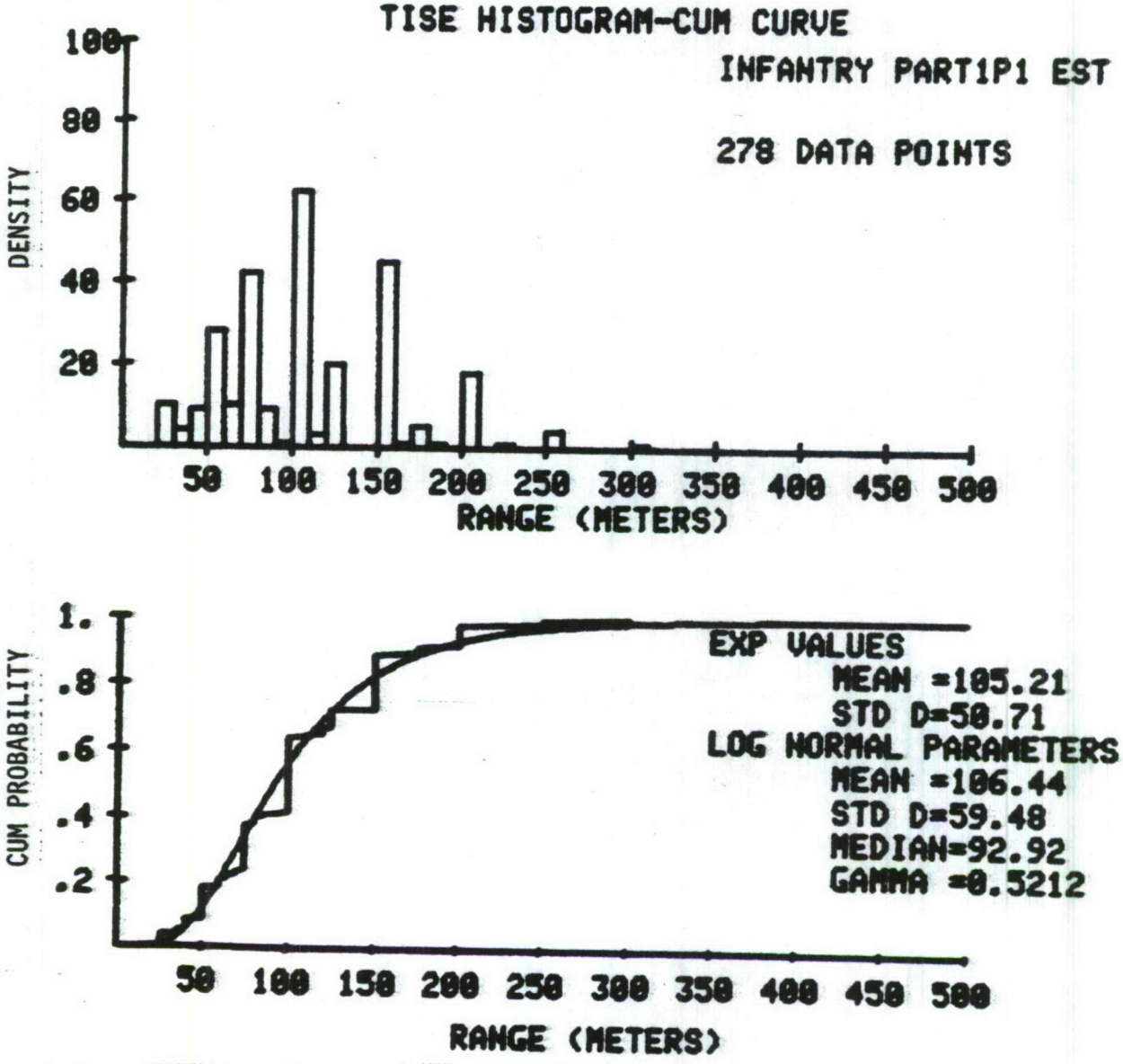

Figure 6. TISE part I phase 1, estimated target ranges at recognition by infantry, single target vehicle

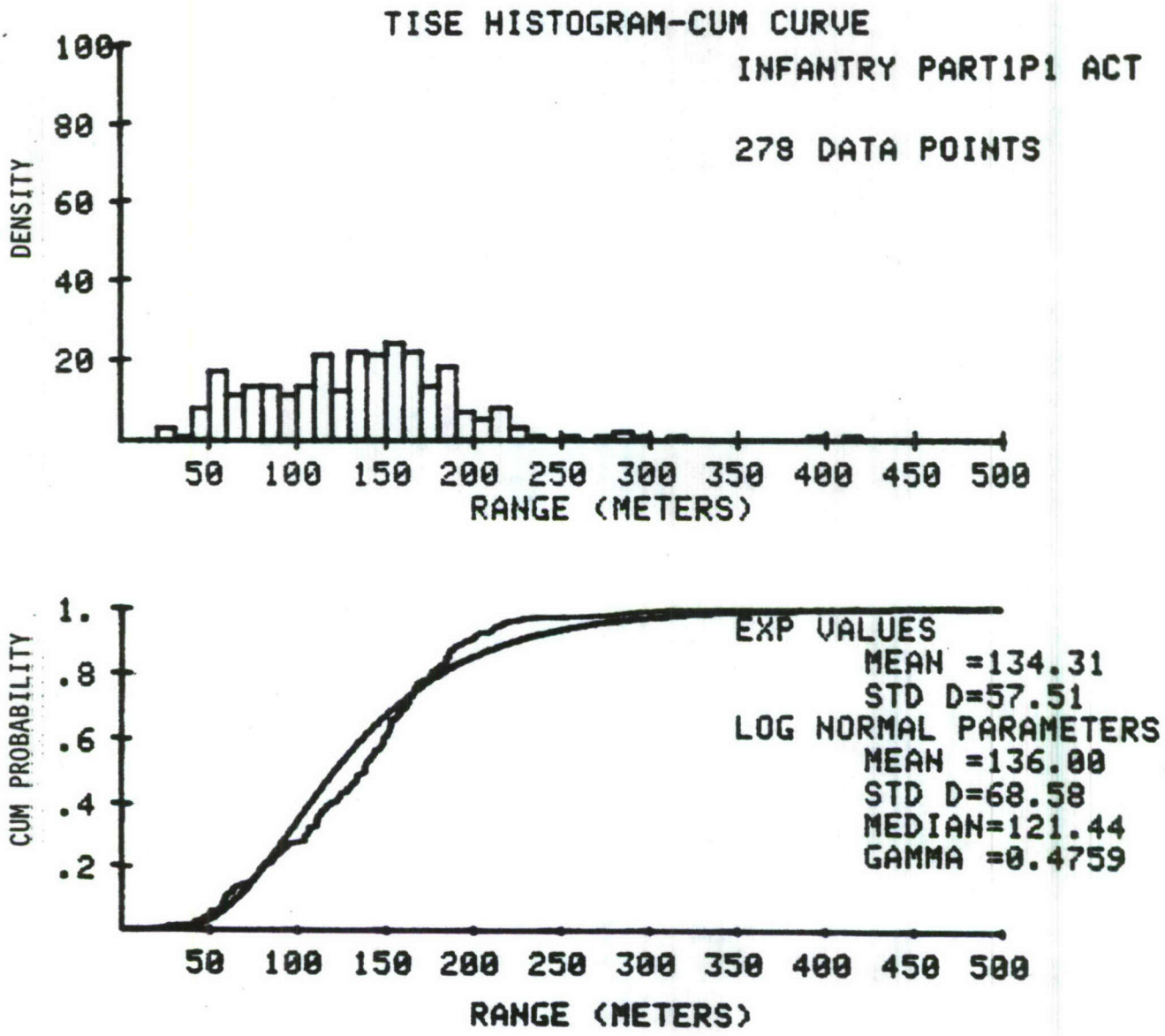

Figure 7. TISE part I phase 1, actual target ranges at recognition by infantry, single target vehicle

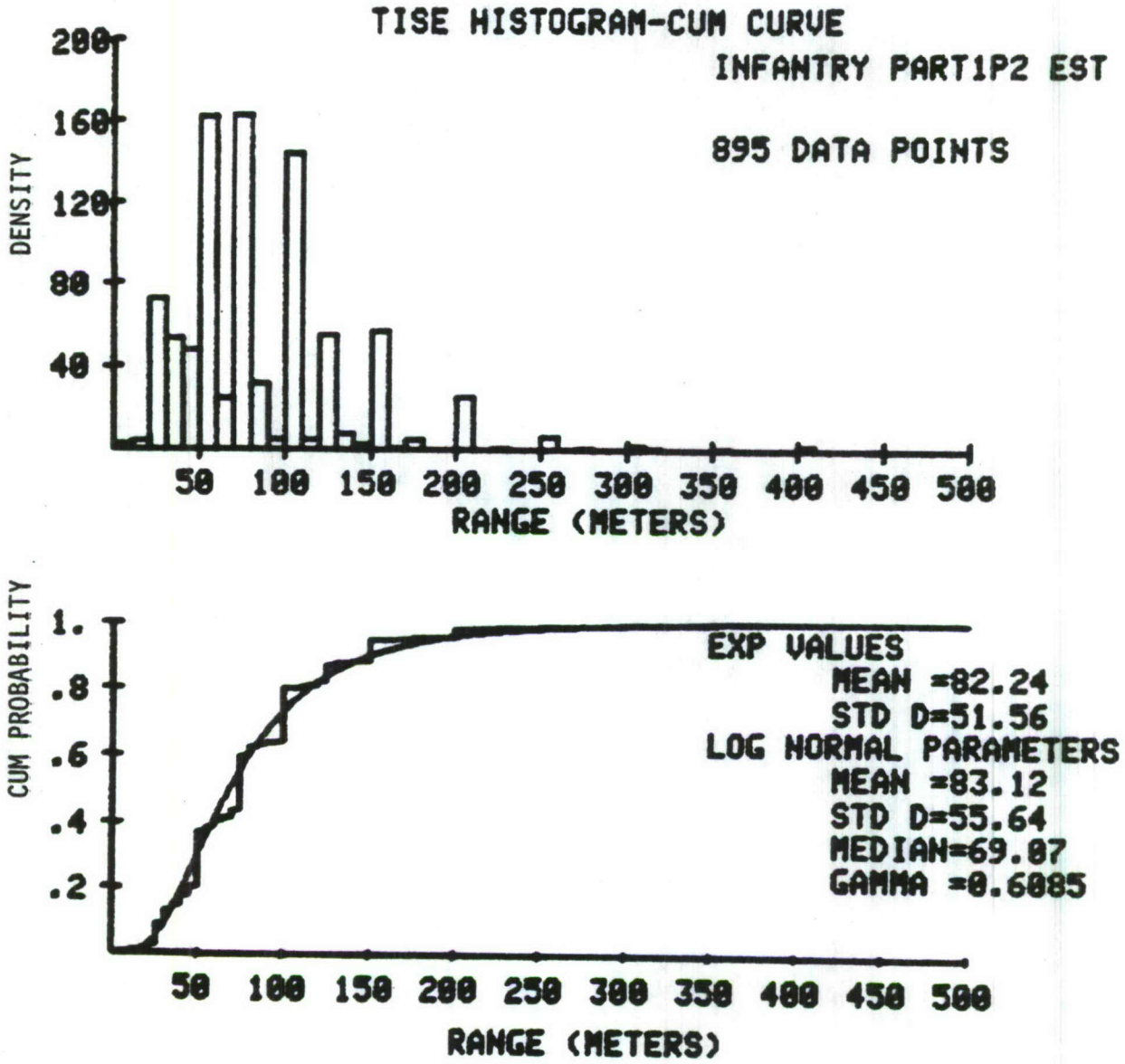

Figure 8. TISE part I phase 2, estimated target ranges at recognition by infantry, multiple targets

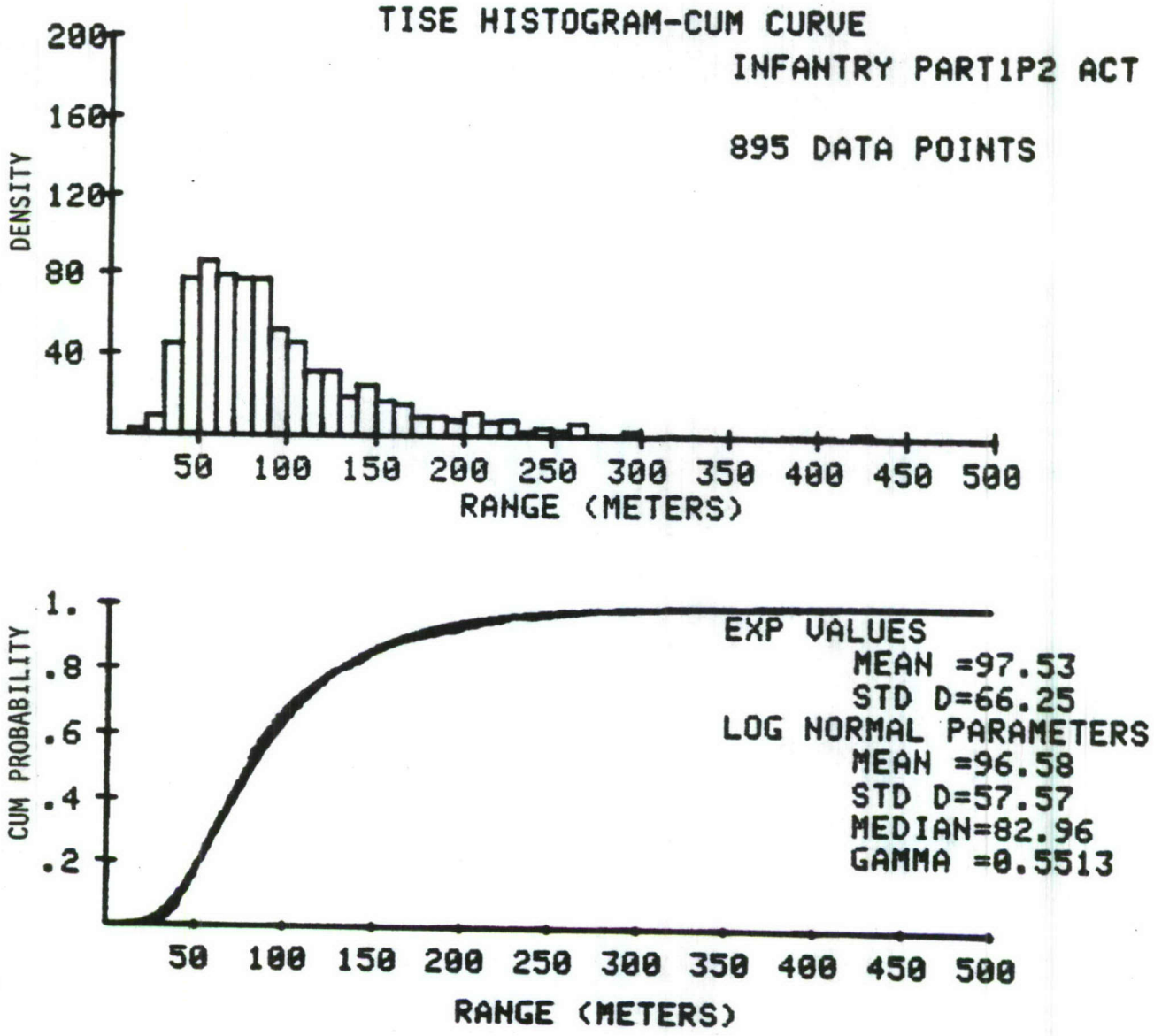

Figure 9. TISE part I phase 2, actual target ranges at recognition by infantry, multiple targets

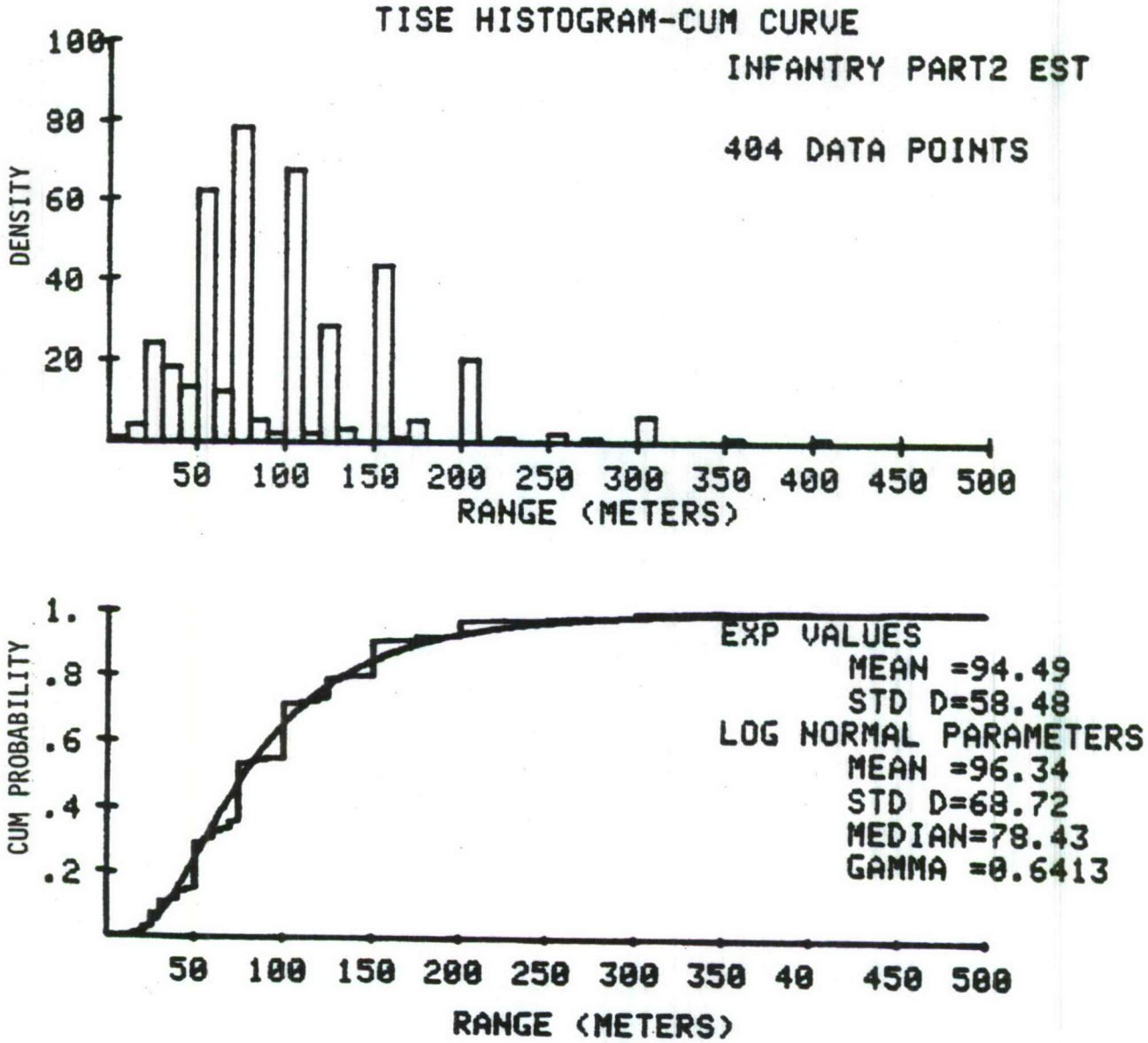

Figure 10. TISE part II, estimated target ranges at recognition by infantry, moving armor force

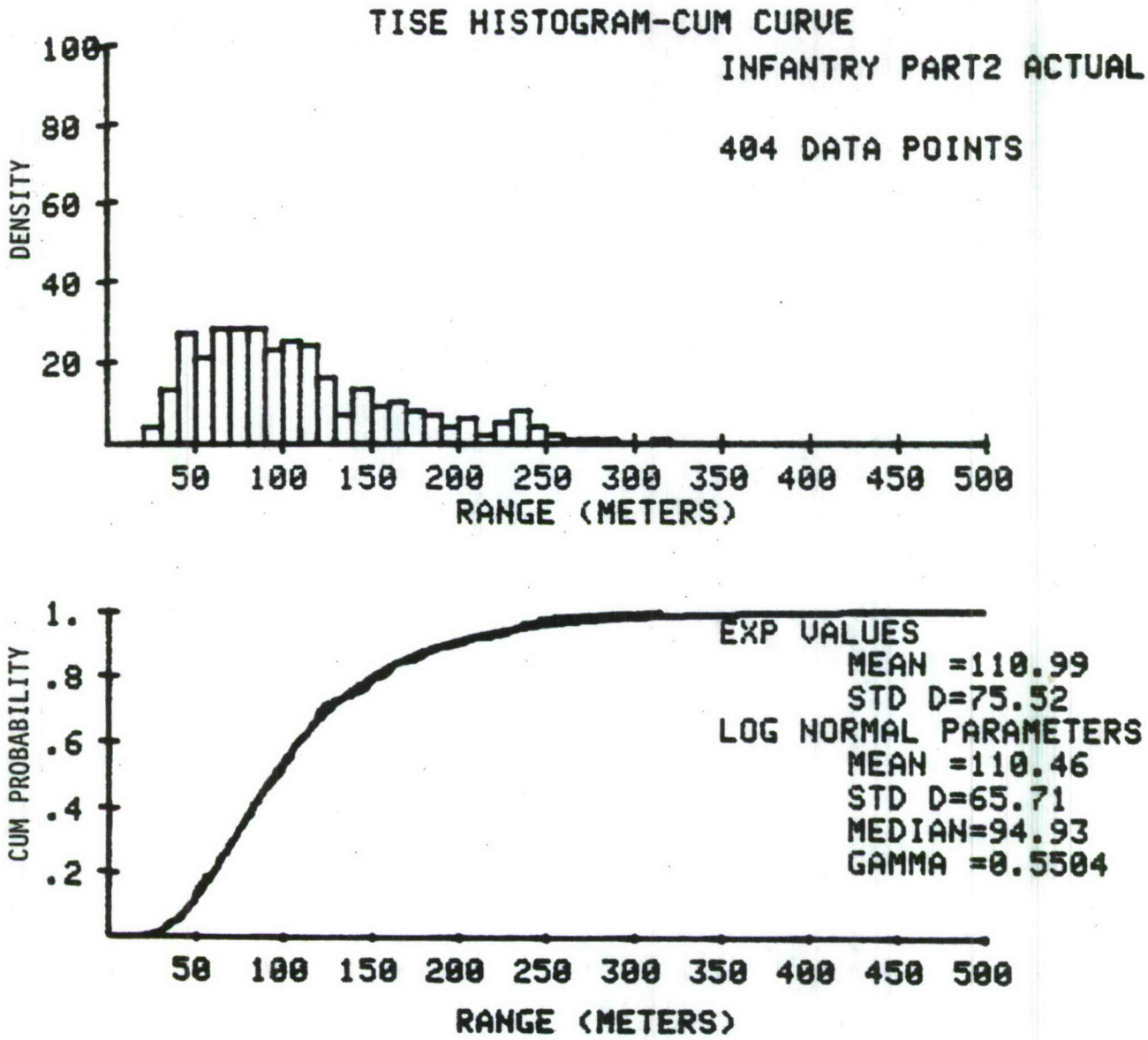

Figure 11. TISE part II, actual target ranges at recognition by infantry, moving armor force

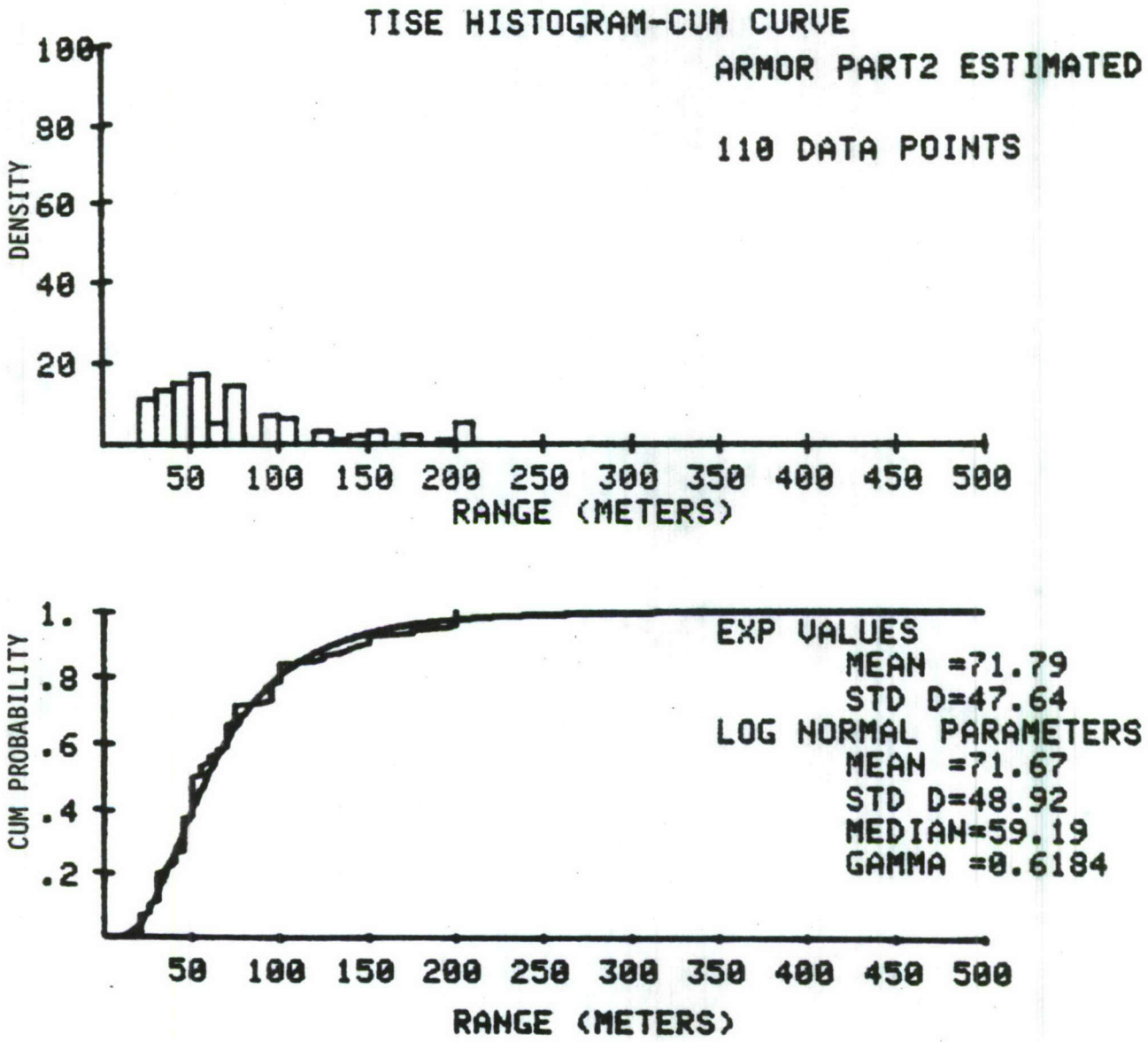

Figure 12. TISE part II, estimated target ranges at recognition by moving armor force

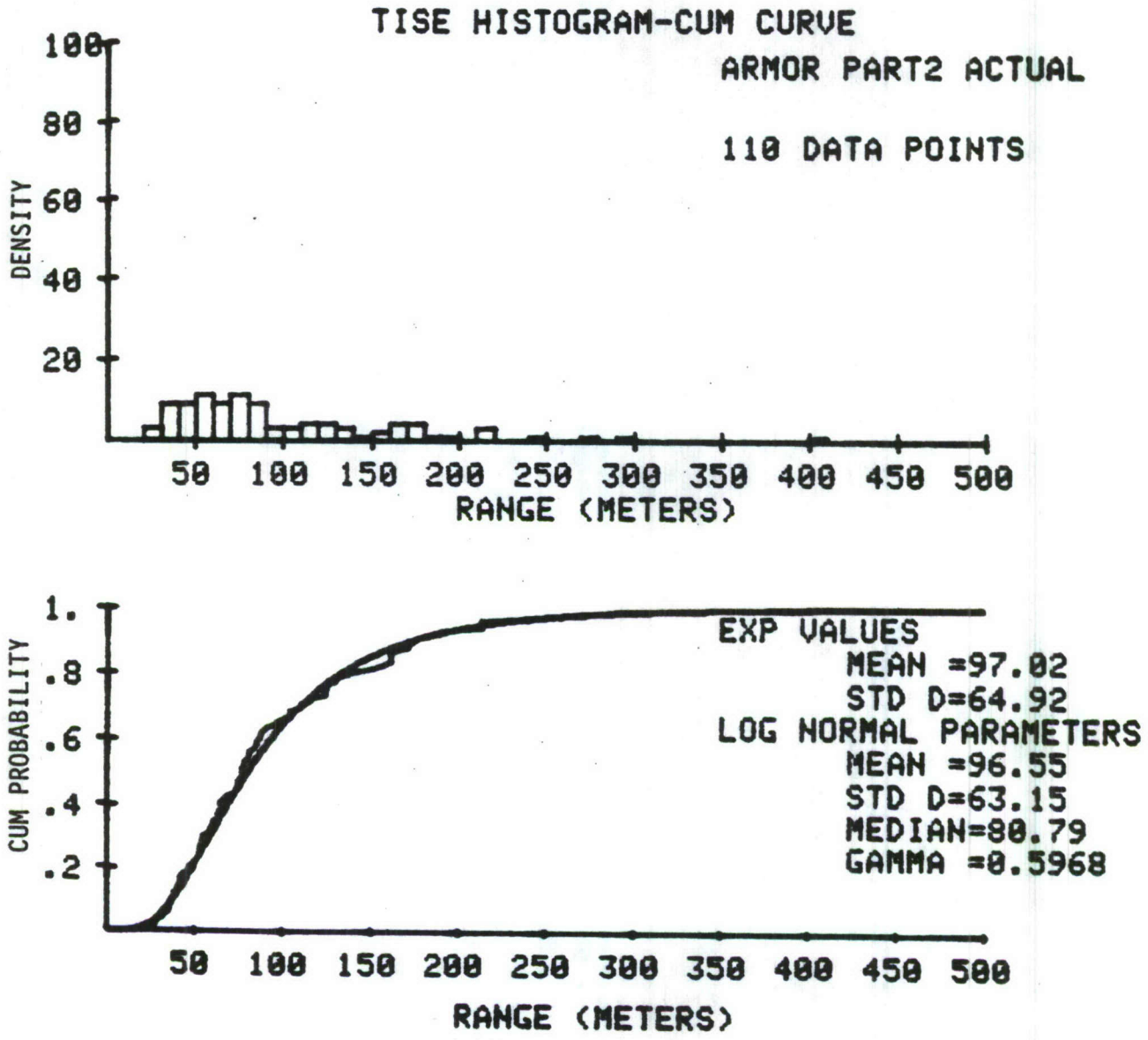

Figure 13. TISE part II, actual target ranges at recognition by moving armor force

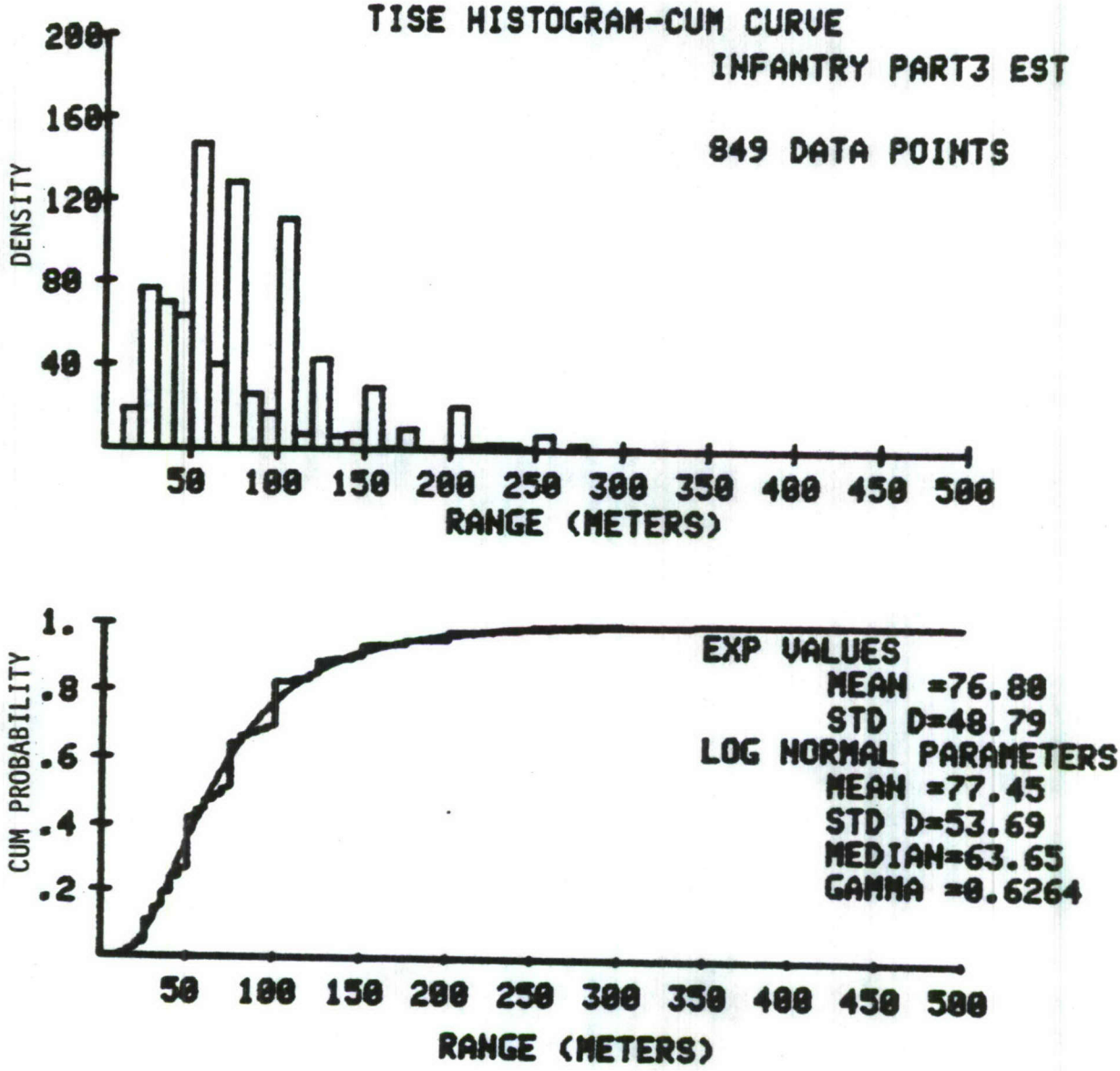

Figure 14. TISE part III, estimated target ranges at recognition by a moving infantry squad, stationary armor

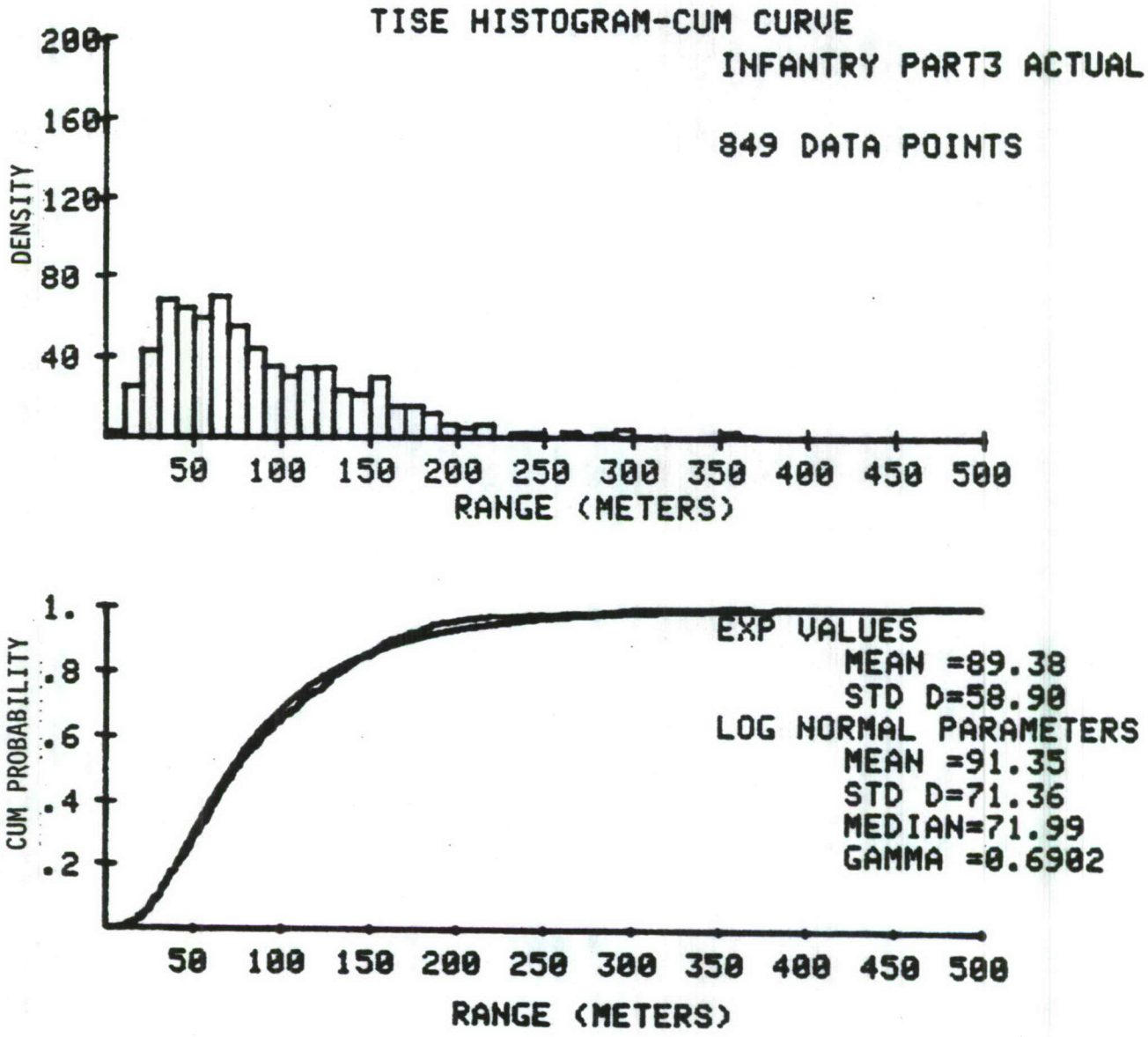

Figure 15. TISE part III, actual target ranges at recognition by a moving infantry squad, stationary armor

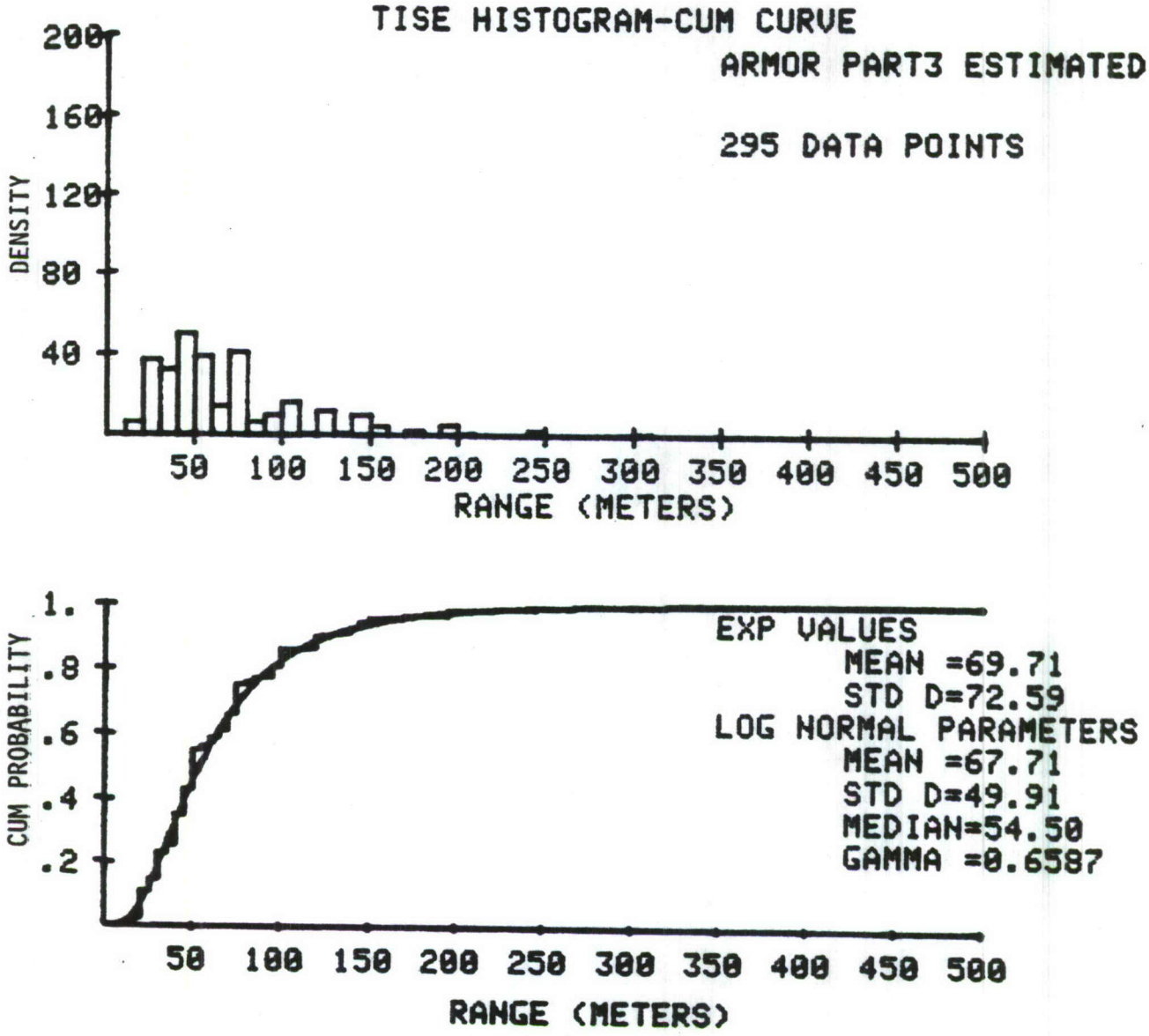

Figure 16. TISE part III, estimated target ranges at recognition by stationary armor of moving infantry squad

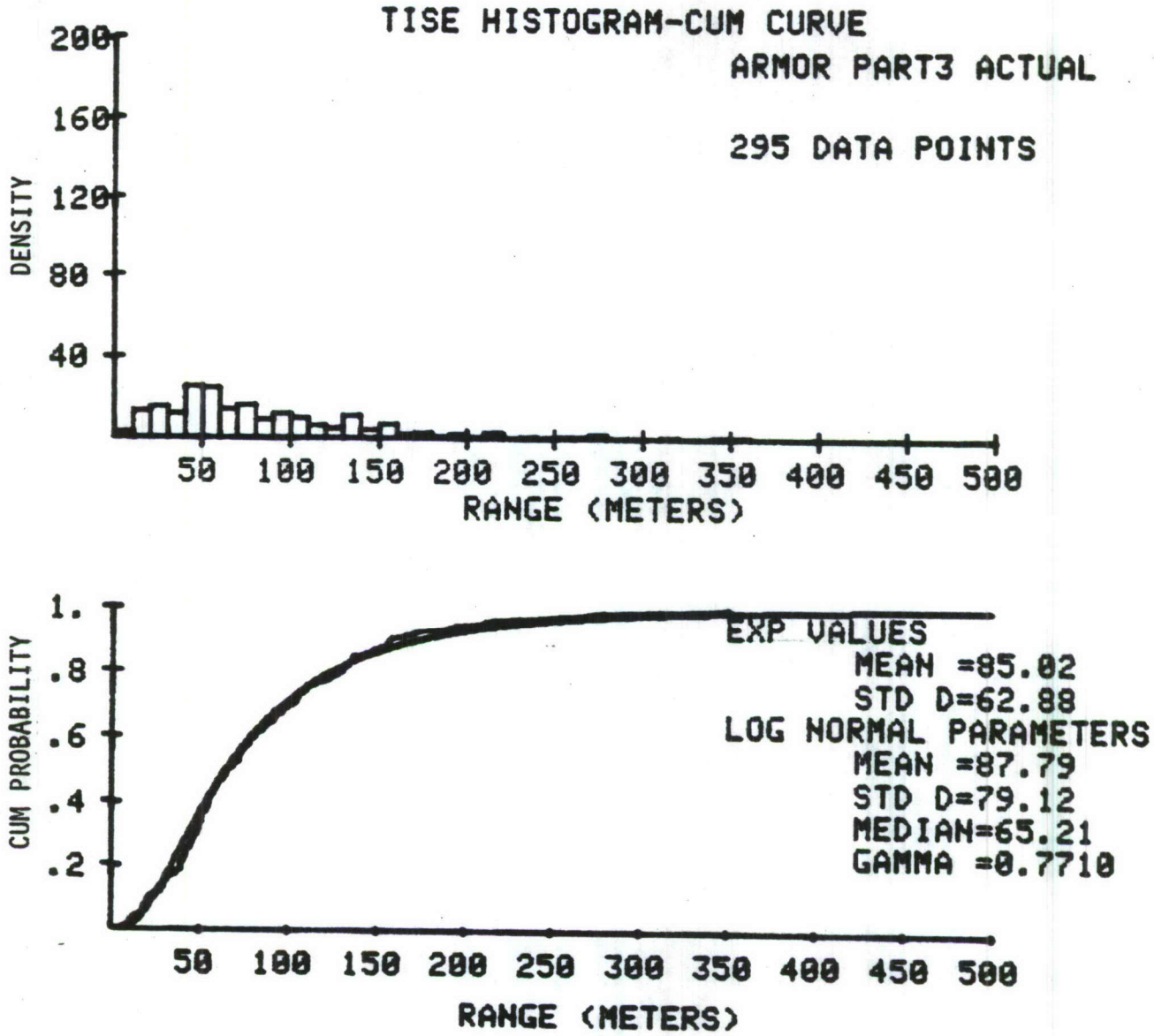

Figure 17. TISE part III, actual target ranges at recognition by stationary armor of moving infantry

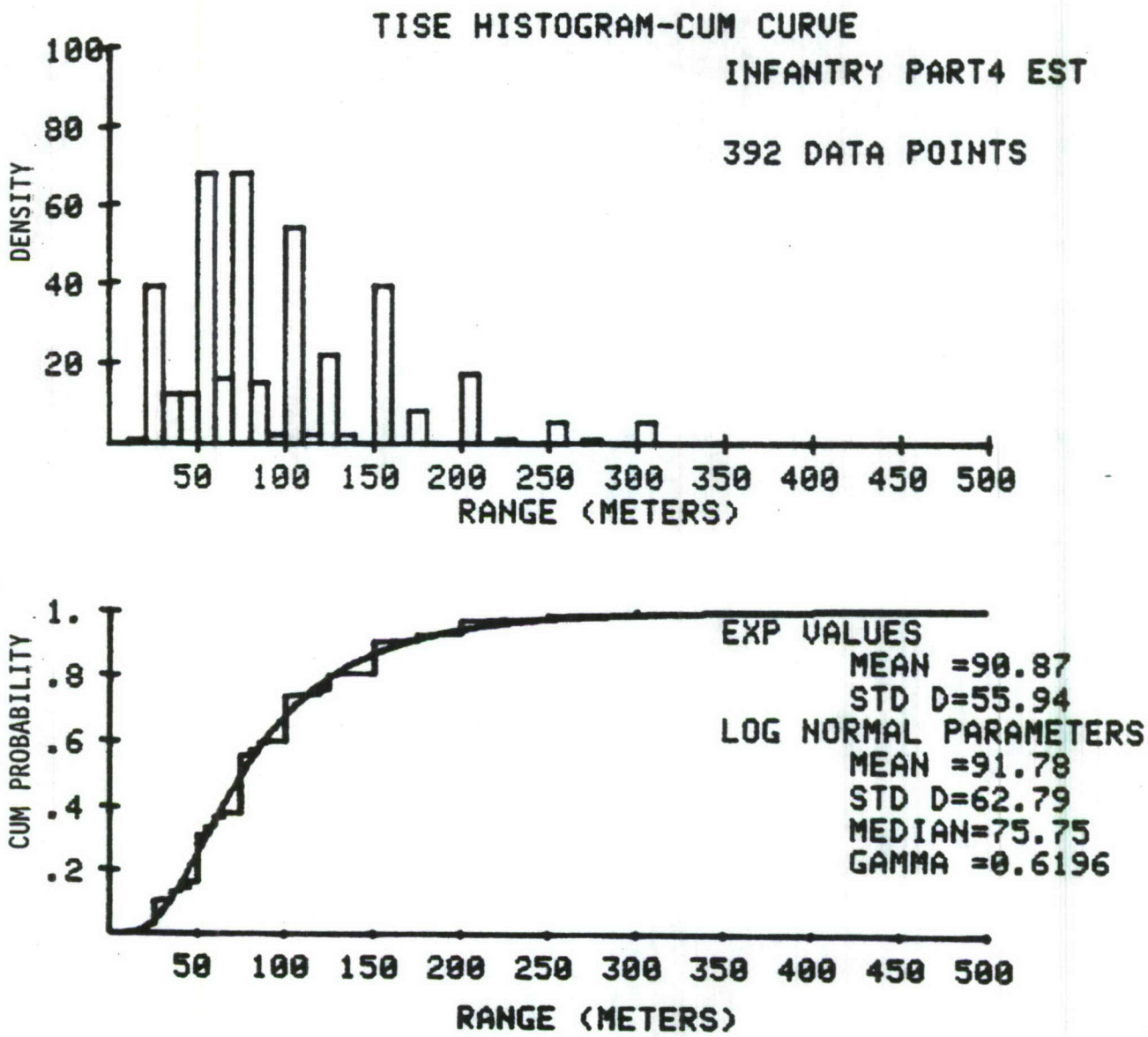

Figure 18. TISE part IV, estimated target ranges at recognition by infantry, moving armor force

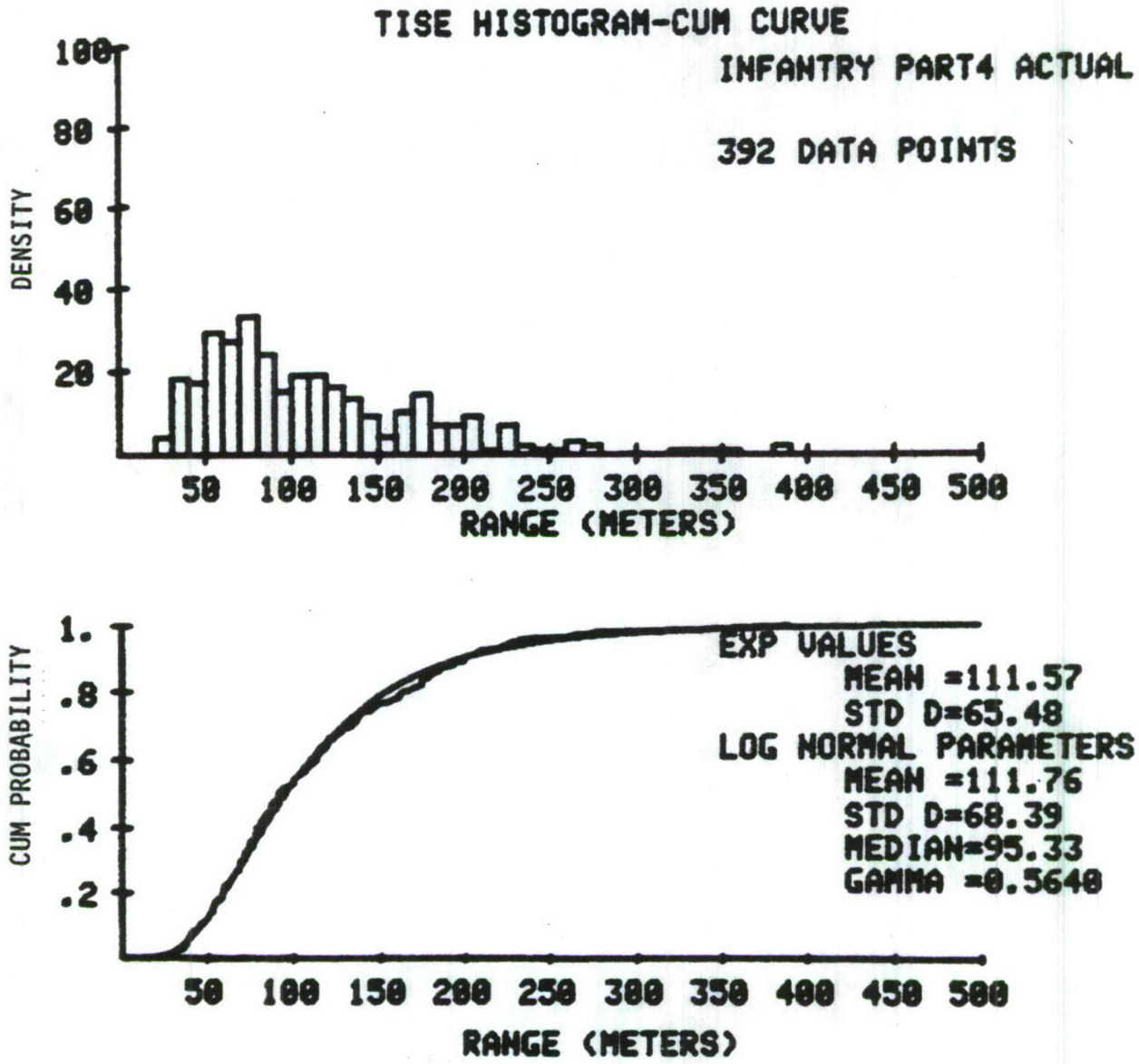

Figure 19. TISE part IV, actual target ranges at recognition by infantry, moving armor force

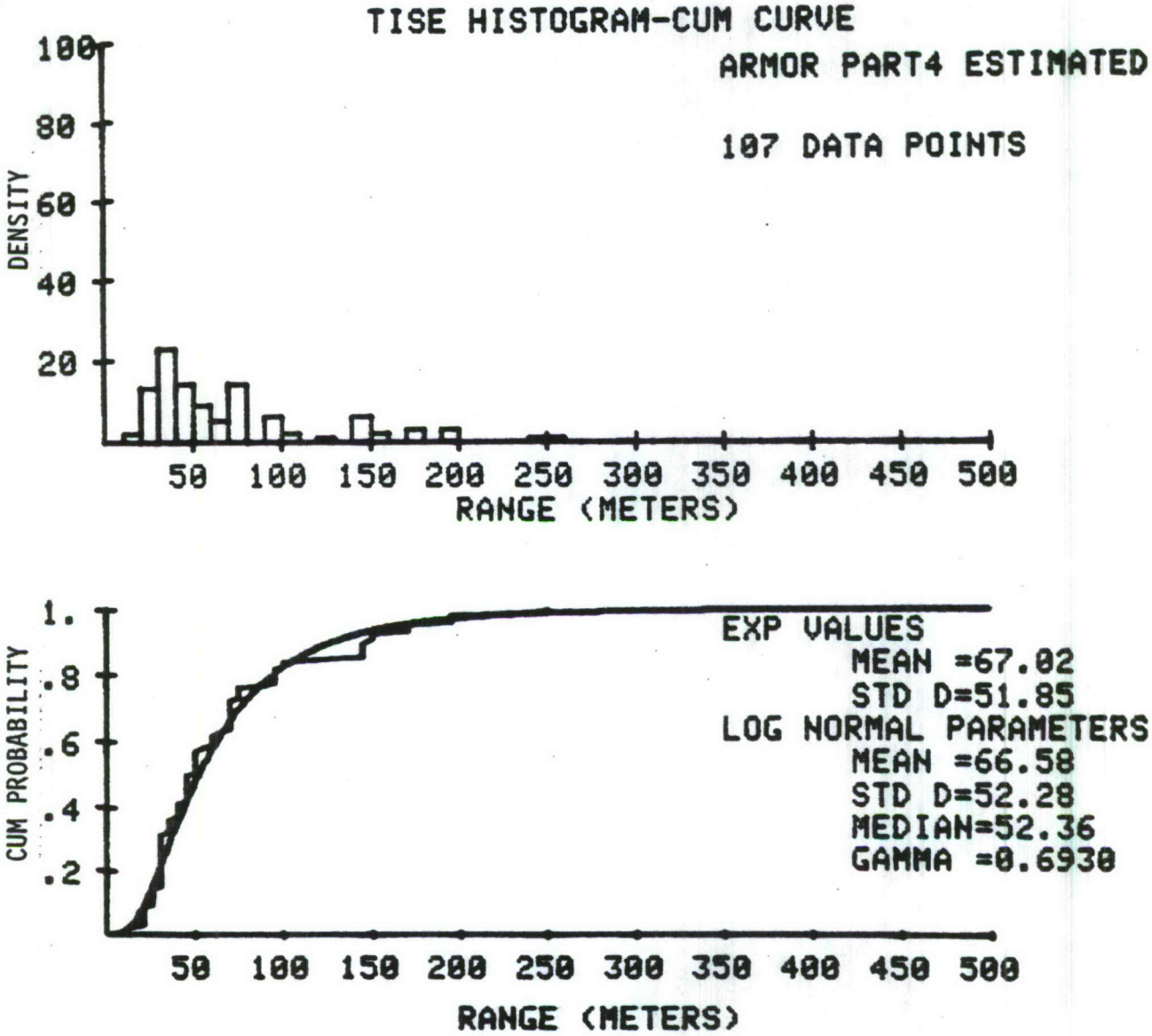

Figure 20. TISE part IV, estimated target ranges at recognition by moving armor force

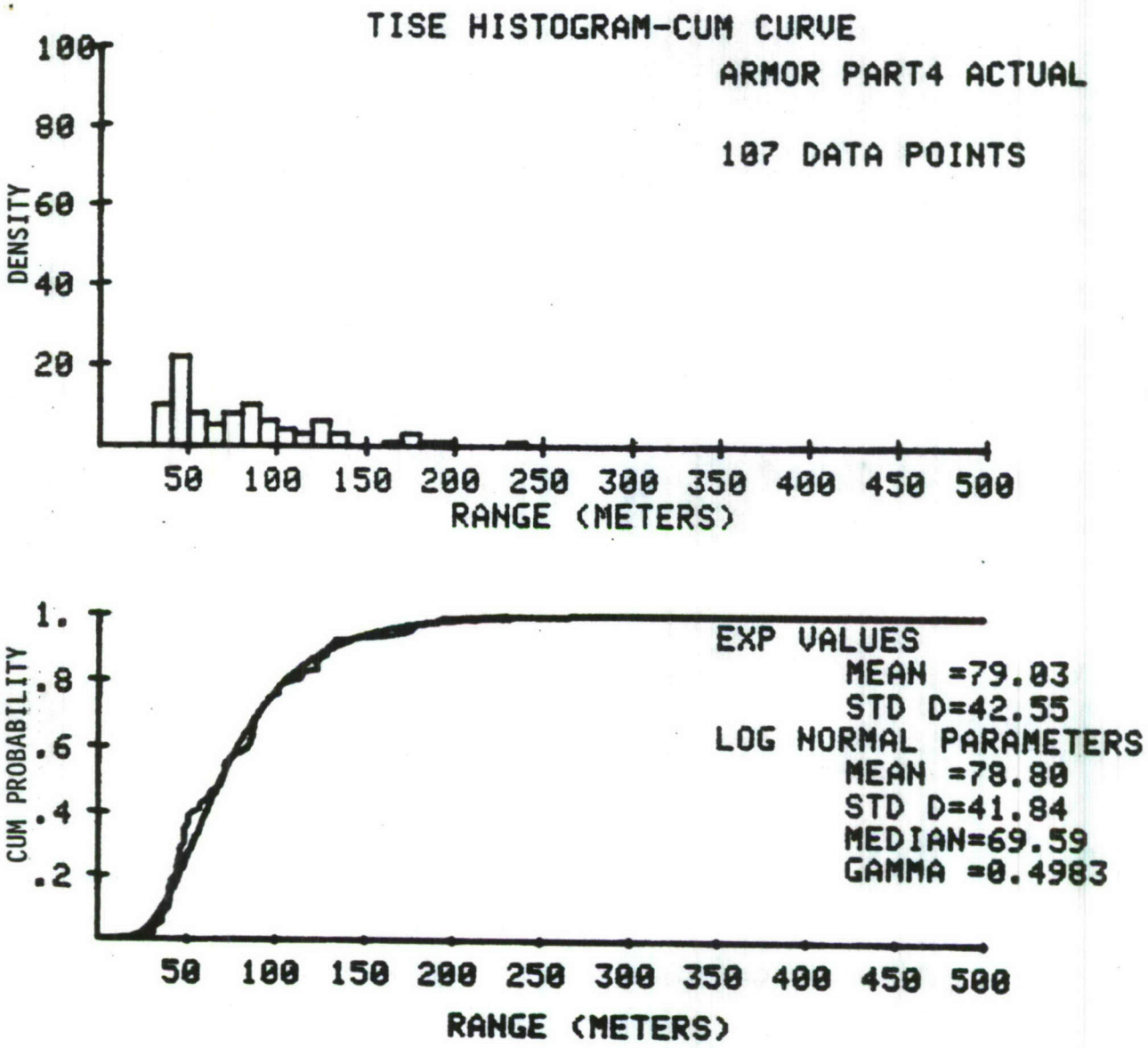

Figure 21. TISE part IV, actual target ranges at recognition by moving armor force

Table 2. Percentages of estimated values less the actual

		Range	Speed
Infantry			
Part I, Phase 1		72	50
Part I, Phase 2		63	76
Part II		62	74
Part III		59	--
Part IV		66	61
	Overall	64	65

		Range	Speed
Armor			
Part II		64	--
Part III		60	--
Part IV		68	--
	Overall	64	

(2) A K-S test to test for significant differences within and between the armor and infantry times of detection and ranges at recognition in parts II, III, and IV was conducted. None of the comparisons tested resulted in any significant differences between armor and infantry responses or caused by the independent variables.

(3) Infantry players consistently and correctly recognize armor targets, with 98 percent correct recognitions for the entire test. Armor personnel did considerably worse, with only 43 percent correct recognitions in part II trials and 52 percent in part IV. (Part III is excluded as all infantry were in a standing posture as they moved down the playing area.) The high rate achieved by the infantry can be attributed to the distinctly different sounds of the APC and M60A1 tank. Post-trial debriefings of the players gave the sound of vehicles as the major cueing factor. On the other hand, armor players had to determine if the target was standing, kneeling, or in a foxhole, a much more difficult task when in a moving vehicle with smoke obscuring and distorting images.

b. Part I, Phases 1 and 2. Data in these two phases were collected from infantry players only. Three postures were used: standing, kneeling, and prone. Armor vehicles fired simulators in a portion of the trials to test for a cueing effect. Both single and multiple vehicle trials were run. Tables 3 and 4 present the average responses for individual cells of the matrix,

Table 3. Averages part I, phase 1 individual matrix cells (time in seconds, range in meters)

	Tank						APC					
	Firing			Nonfiring			Firing			Nonfiring		
	Lanes			Lanes			Lanes			Lanes		
	1	2	3	1	2	3	1	2	3	1	2	3
time to detection	49	85	84	64	55	55	89	86	106	99	66	57
time to recognition	55	89	88	73	60	65	92	91	105	100	69	62
time from detection to recognition	6	8	4	8	5	2	1	3	2	3	3	3
estimated target range	86	113	88	111	124	102	80	95	87	112	126	102
actual target range	110	159	90	161	161	167	99	118	85	135	148	127
estimated target speed	2.84	2.38	2.44	2.58	2.5	2.29	2.55	2.38	2.08	1.94	2.56	3.4
actual target speed	1.92	2.72	3.00	2.35	3.44	2.76	1.65	3.29	2.83	1.78	2.68	1.35
no. correct recognitions	25	27	9	25	16	16	20	21	12	18	34	19
no. incorrect recognitions	0	0	0	0	0	1	0	0	0	0	0	1

Table 4. Averages part I, phase 2 individual matrix cells (time in seconds, range in meters)

			Armor			
			Line		Wedge	
			Firing	Non-firing	Firing	Non-firing
INFANTRY	SQUAD 1	time to detection	121	109	140	109
		time to recognition	121	111	142	112
		estimated target range	70	85	99	79
		actual target range	63	96	103	84
		no. correct recognitions	60	100	138	84
		no. incorrect recognitions	1	3	2	0
	SQUAD 2	time to detection	133	129	124	135
		time to recognition	136	132	126	133
		estimated target range	90	71	66	67
		actual target range	92	67	78	65
		no. correct recognitions	148	75	66	102
		no. incorrect recognitions	4	2	5	1

infantry in table 3 and armor in table 4. Wilcoxen and K-S tests were conducted for the following independent variable combinations:

- individual matrix cells
- infantry/armor posture comparisons
- armor vehicle type
- firing/nonfiring
- armor vehicle formation

The Wilcoxen test compared the estimated to actual target ranges and speeds at recognition. The K-S test was used to determine the effects of the independent variables on reaction times, ranges, and speeds. In every case the test used resulted in no significant difference. Figures 22 and 23 show distribution of ranges for firing versus nonfiring armor vehicles in part I, phase 2. Note, on the average, firing vehicles were detected at somewhat longer ranges than in trials with no firing vehicles. However, this difference proved to be not statistically significant (α = .05 level of significance). The reader is referred to the USACDEC final report and military observations for a more indepth discussion of this cueing effect. Overall the infantry players underestimated the target range in 72 percent of the recorded responses in phase 1 and 63 percent in phase 2. Figures 24 and 25 show the range of the absolute differences between these recorded responses. The average difference was 48 meters in phase 1 and 40 meters in phase 2.

c. Part II. Data in part II were collected from both the armor crews and infantry players. LAW simulators were fired by the infantry in all postures for a portion of the trials. Armor crews were in both open and closed postures. The results are given in table 5 for the infantry responses and table 6 for the armor. Analysis of the data for the infantry players showed no statistical difference for reaction times and ranges between buttoned and unbuttoned vehicles or tanks as opposed to APCs. Armor personnel reaction times were quicker for unbuttoned vehicles, but ranges at time of recognition in both cases were approximately equal. Further analysis showed these differences were not statistically significant. Comparison of firing and nonfiring trials resulted in cueing having no significant effect on armor crew ability to detect the infantry players. Armor crews consistently did poorly at estimating target ranges throughout this portion of the experiment. In this particular part the Wilcoxen matched pairs test on estimated versus actual target ranges resulted in significance in three of the four factor combinations (armor unbuttoned/infantry firing, armor unbuttoned/infantry nonfiring, and armor buttoned/infantry firing). Only the trials where armor crews were buttoned and infantry were nonfiring did the test show no significant variation. Figures 26 through 29 display the armor crew estimates of target range and the actual target range. Figures 26 and 28 are when

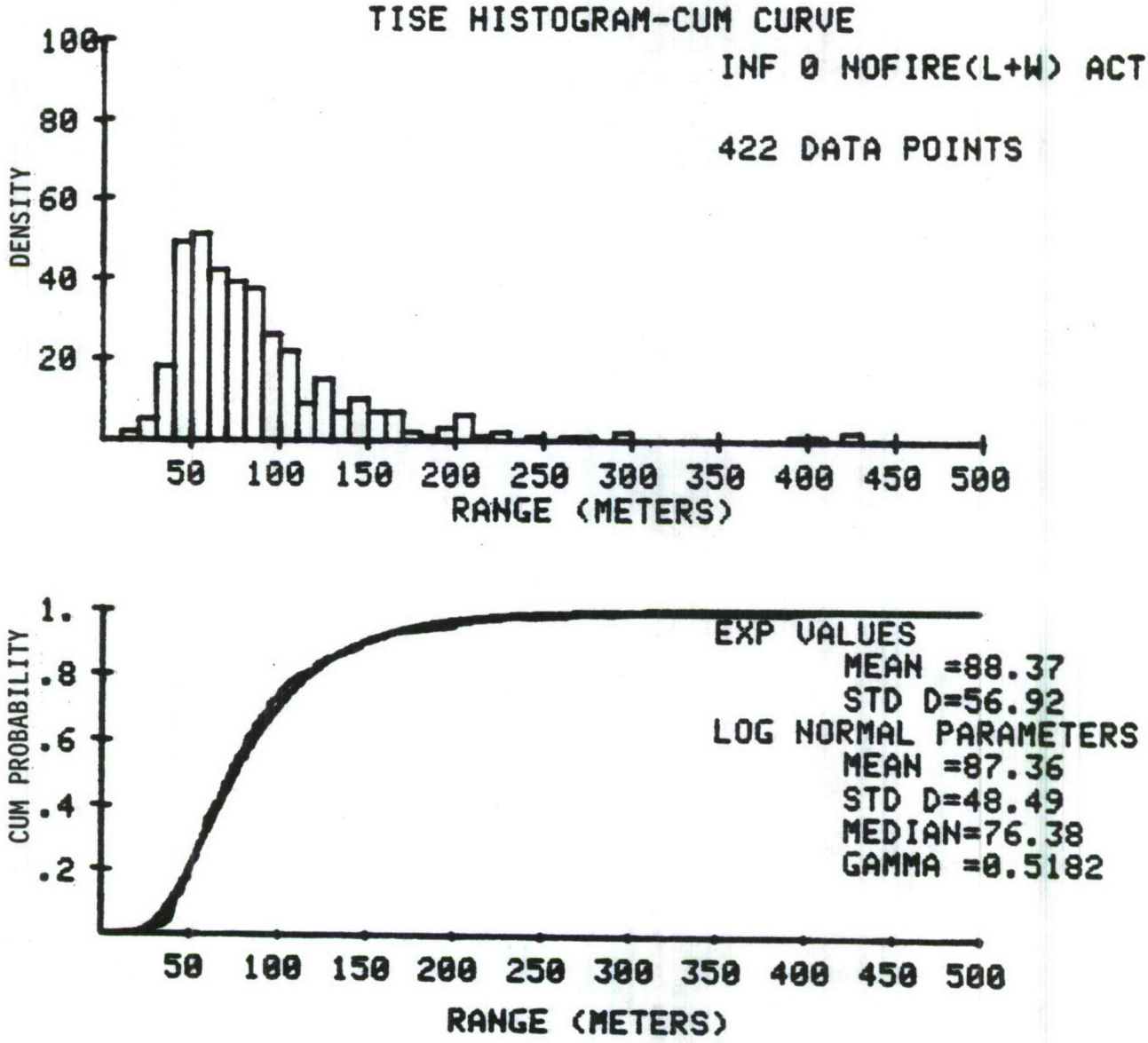

Figure 22. TISE part I phase 2, actual target ranges at recognition by infantry of nonfiring armor

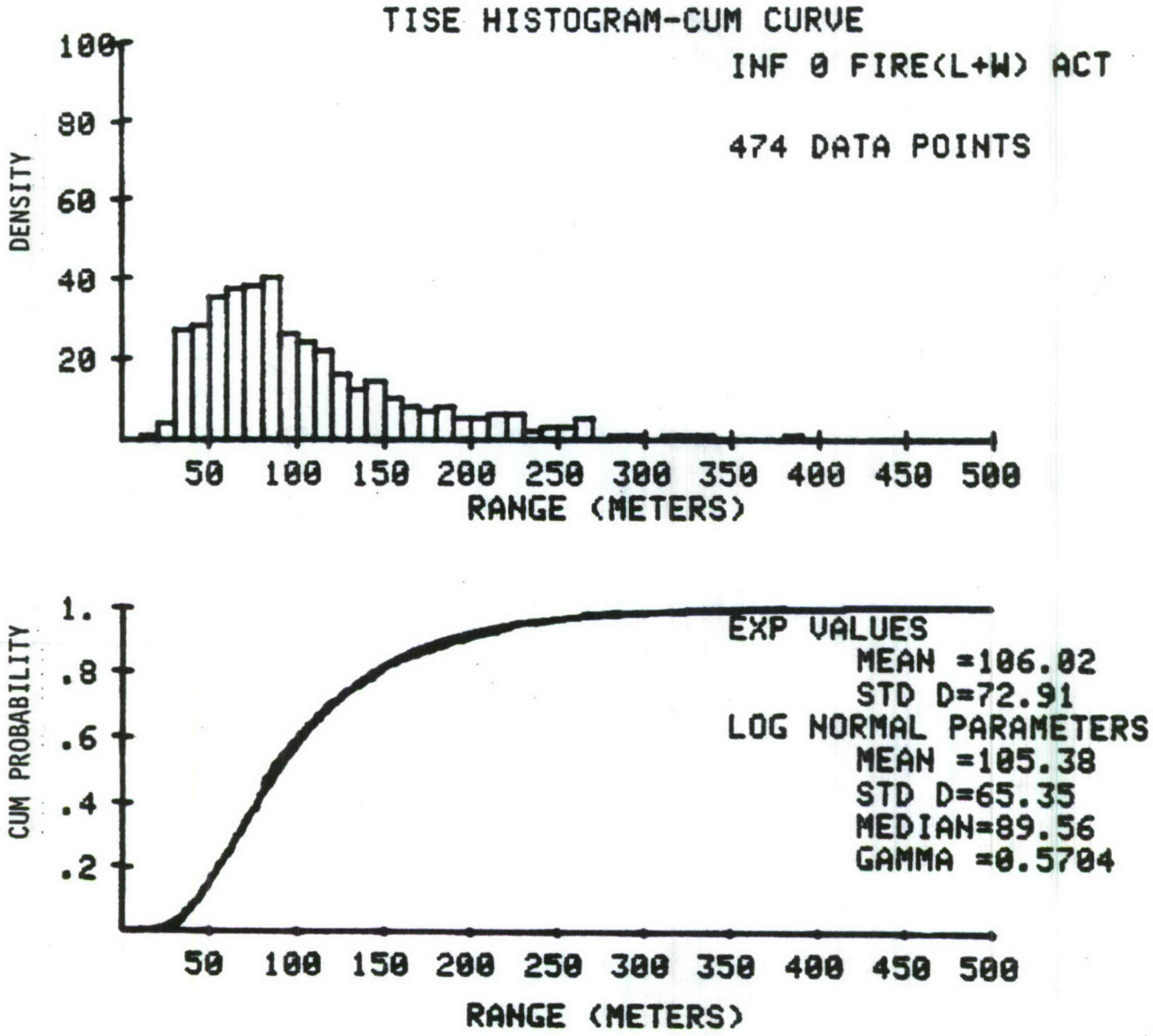

Figure 23. TISE part I phase 2, actual target ranges at recognition by infantry of firing armor

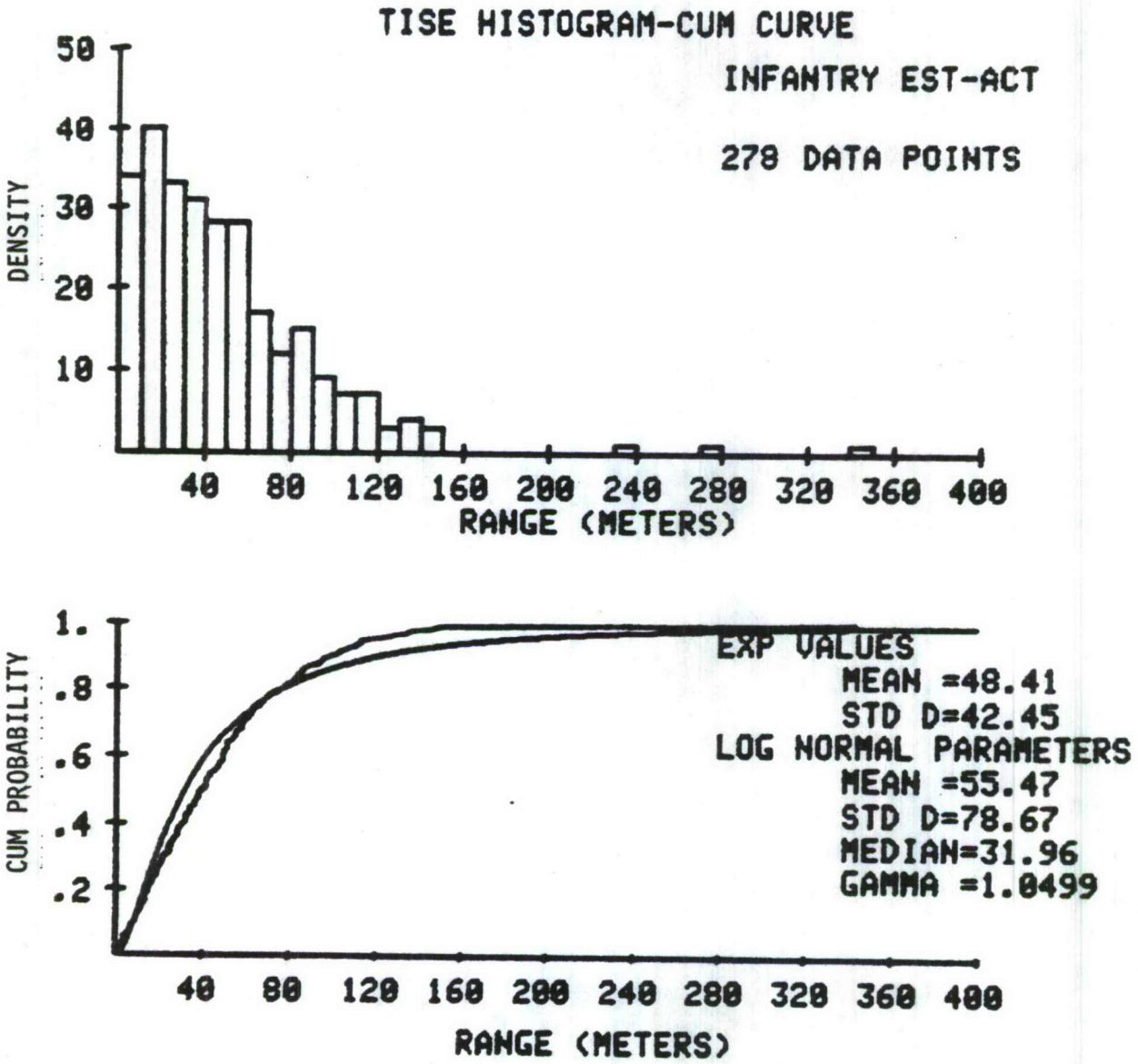

Figure 24. TISE part I phase 1, absolute difference between estimated and actual ranges at recognition by infantry

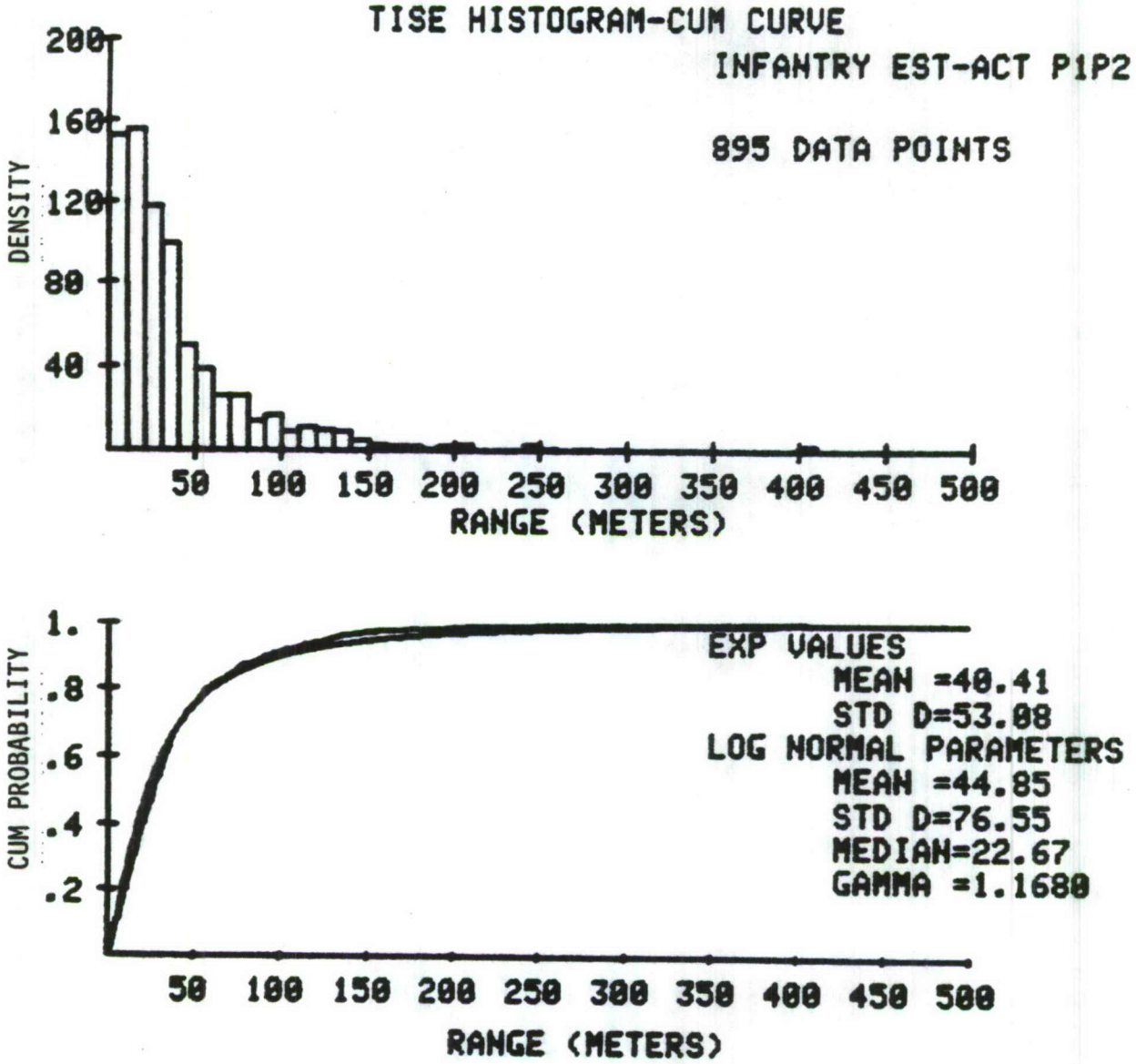

Figure 25. TISE part I phase 2, absolute difference between estimated and actual ranges at recognition by infantry

Table 5. Averages part II infantry responses individual matrix cells (time in seconds, range in meters)

			Armor	
			Buttoned	Unbuttoned
INFANTRY	Firing	time to target detection	98	93
		time to target recognition	98	96
		time to engagement	637	106
		estimated target range	101	78
		actual target range	122	90
		no. correct recognitions	62	69
		no. incorrect recognitions	3	1
	Nonfiring	time to target detection	93	93
		time to target recognition	96	97
		estimated target range	107	84
		actual target range	115	111
		no. correct recognitions	106	71
		no. incorrect recognitions	1	1

Table 6. Averages part II armor responses individual matrix cells (time in seconds, range in meters)

			Armor	
			Buttoned	Unbuttoned
INFANTRY	Firing	time to target detection	102	85
		time to target recognition	105	88
		estimated target range	69	68
		actual target range	95	95
		no. correct recognitions	10	8
		no. incorrect recognitions	18	12
	Nonfiring	time to target detection	95	92
		time to target recognition	103	107
		estimated target range	65	81
		actual target range	89	100
		no. correct recognitions	13	6
		no. incorrect recognitions	9	10

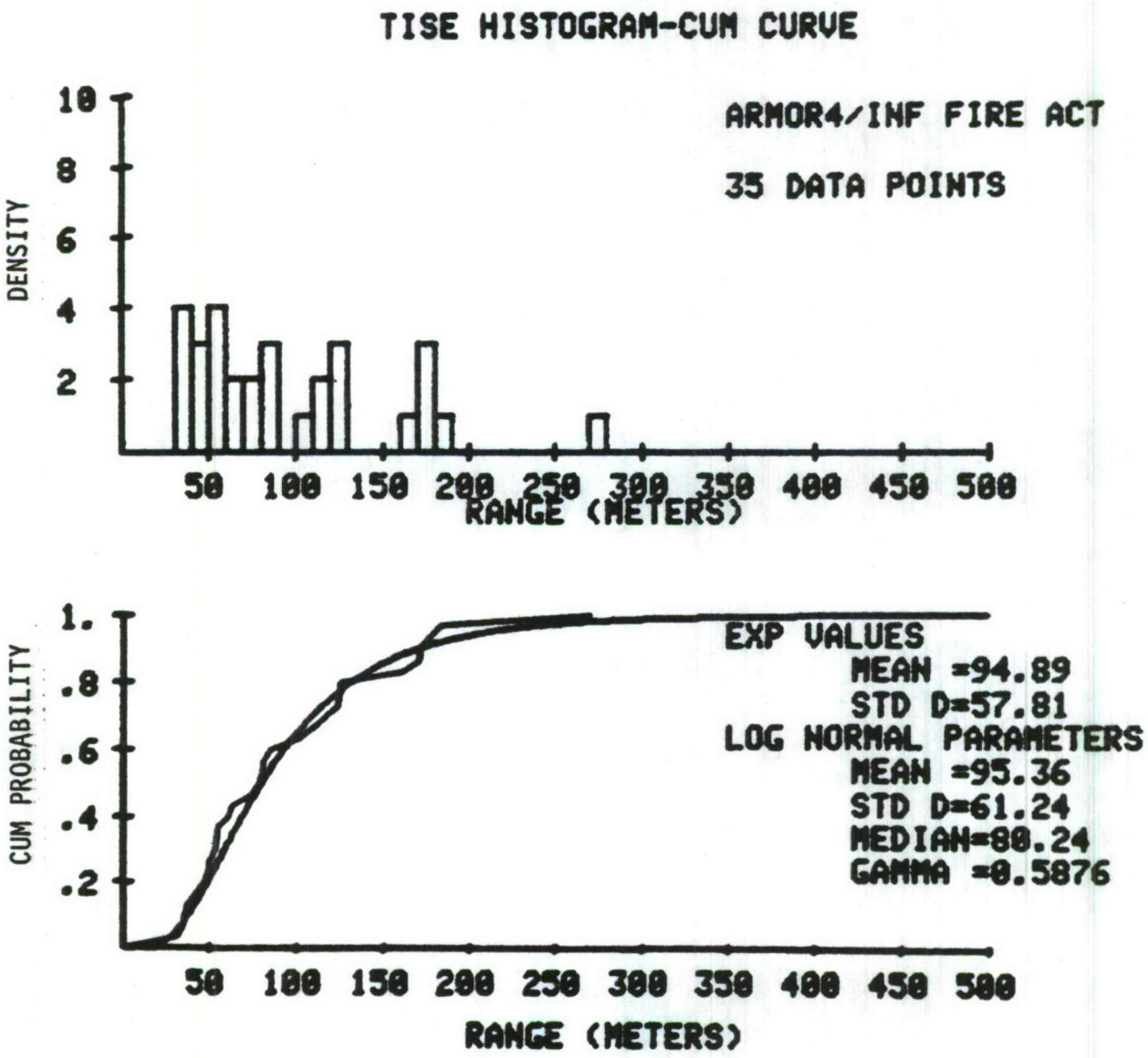

Figure 26. TISE part II, actual target range at recognition of firing infantry by buttoned armor

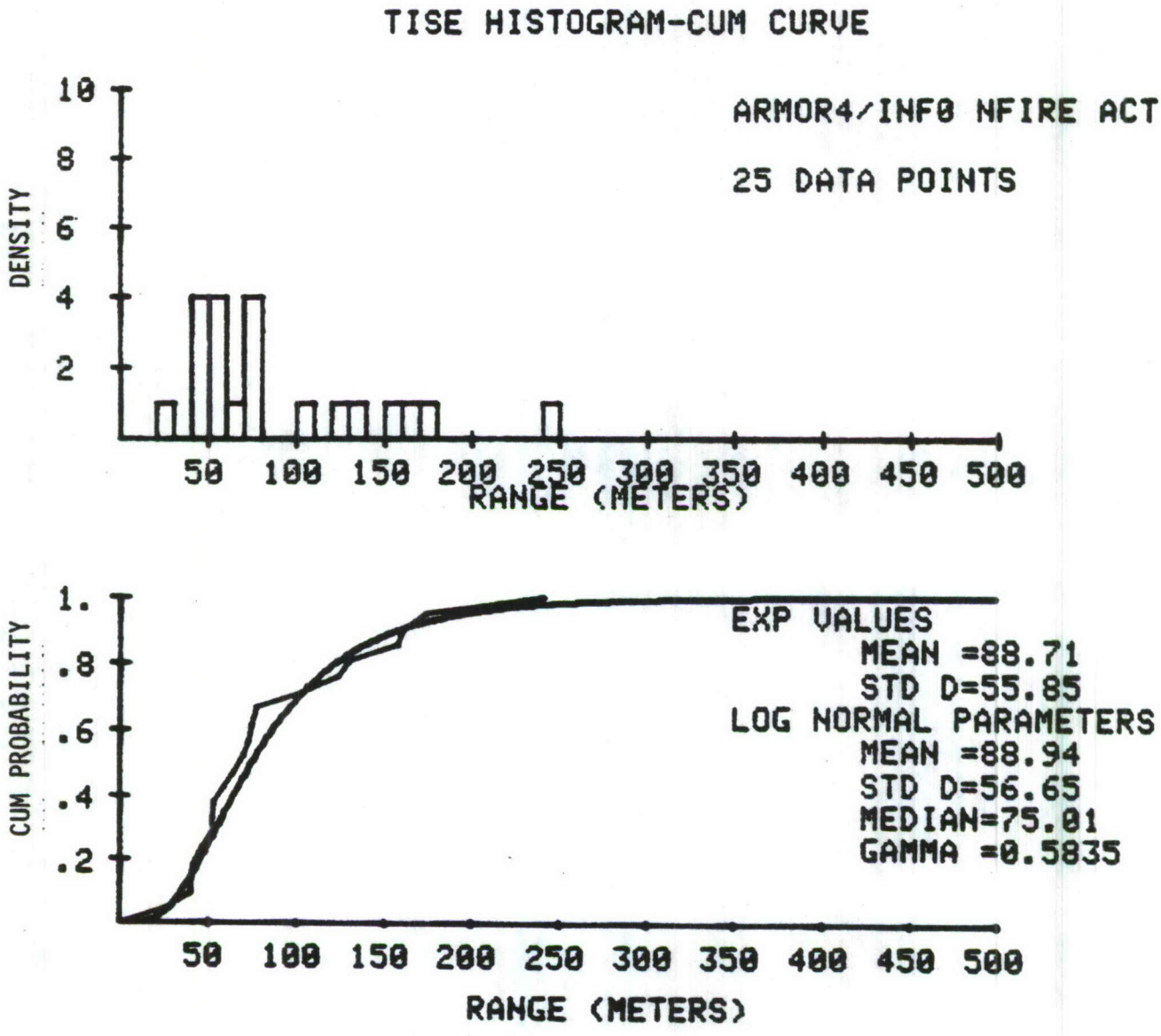

Figure 27. TISE part II, actual target range at recognition of nonfiring infantry by buttoned armor

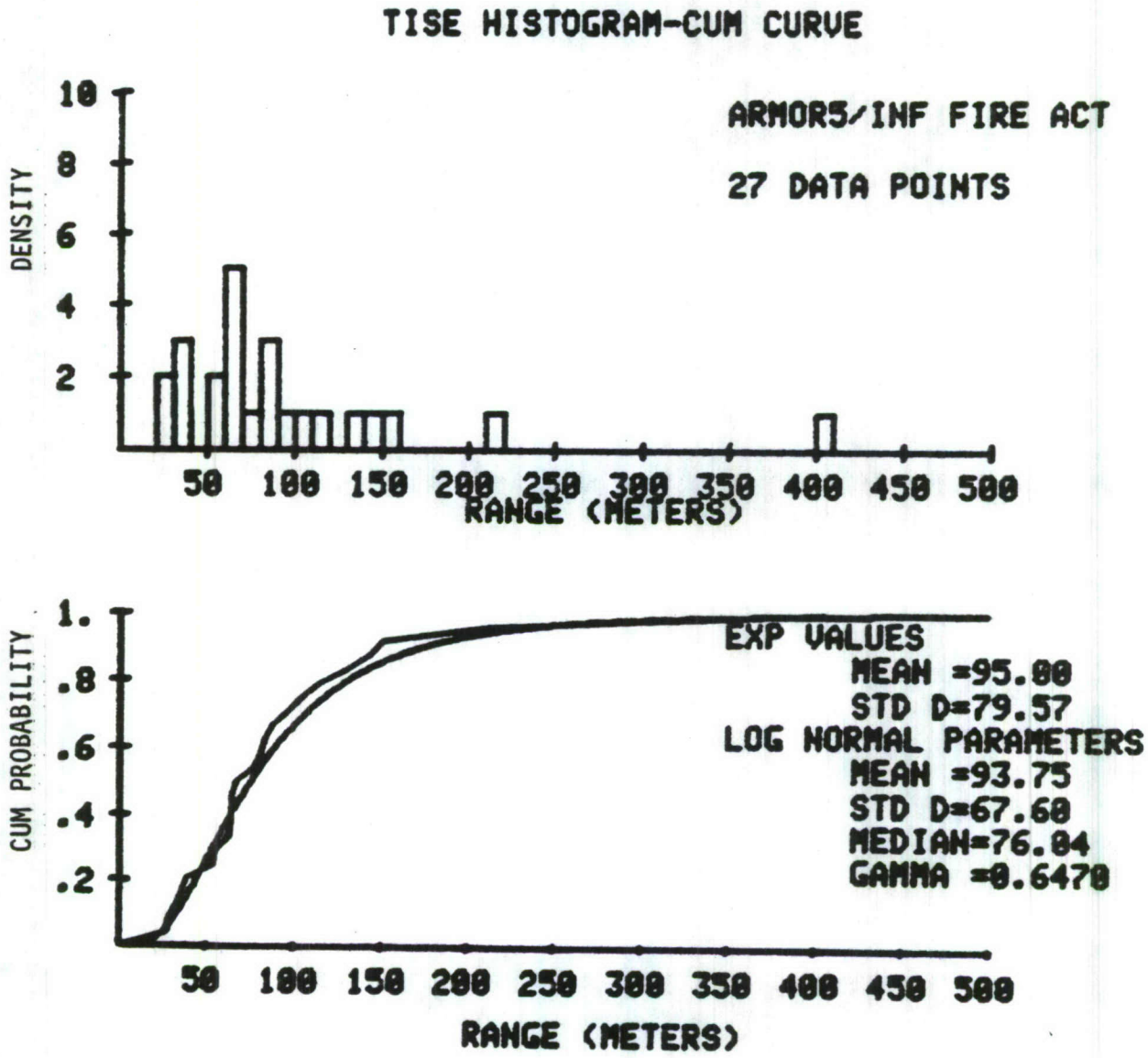

Figure 28. TISE part II, actual target range at recognition of firing infantry by unbuttoned armor

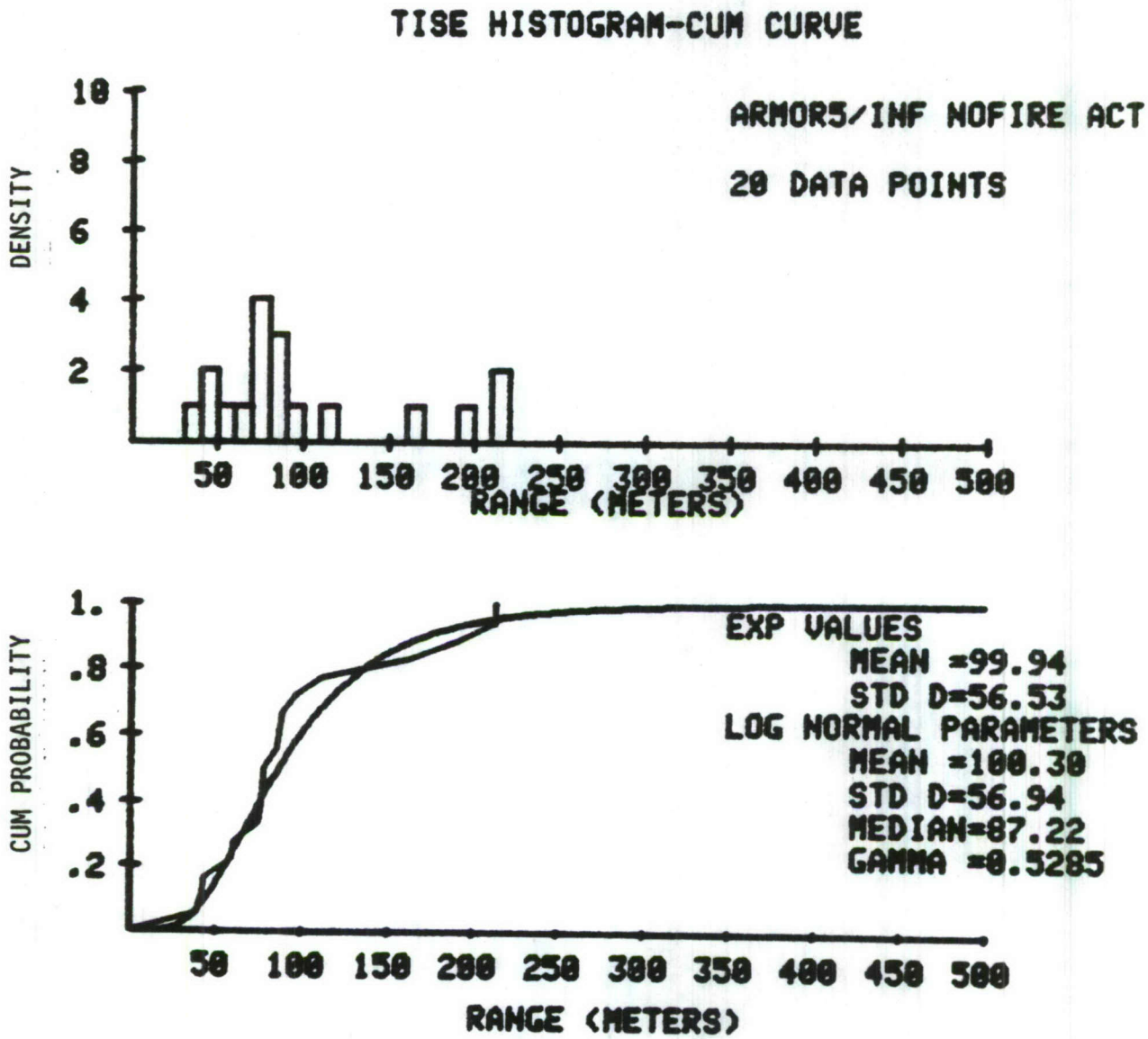

Figure 29. TISE part II, actual target range at recognition of nonfiring infantry by unbuttoned armor

infantry fired the LAW simulators, and figures 27 and 29 are without the cueing factor. Overall the absolute variation between estimated and actual target range at time of recognition averaged 46 meters for infantry players and 52 meters for the armor crews (figures 30 and 31).

d. Part III. Part III trials had the armor vehicles in a stationary position at one end of the playing area. Squads of infantry proceeded on foot down the playing field and attempted to detect and recognize the threat vehicles. Data were collected from both armor and infantry personnel. The results are presented in tables 7 and 8. No statistical difference was found for any factor combination that was investigated. Vehicle type or posture did not affect infantry results nor the responses of the armor crews. As expected, detection ranges dropped markedly. The vehicles did not have their engines on during trials so that cueing of vehicle presence by sound was absent. As in the other parts of the test, a comparison of infantry and armor detection times and recognition ranges resulted in no significant (α = .05) difference. Figures 32 thru 35 show the cumulative curves for the actual target ranges at recognition. Analysis on estimated versus actual range values proved no statistically significant difference between the two for all factor combinations. However, estimated ranges were less than the actual ranges in approximately 59 percent of the responses given, even though on the average the armor crews overestimated the target range in three cells. The infantry averaged a 35-meter variation between estimated and actual target range, while the armor crew average was 43 meters (figures 36 and 37).

e. Part IV. Trials in part IV were free-play engagement exercises, although no casualty assessments were recorded. An infantry platoon occupied tactically chosen positions that differed from those used in the other parts of TISE, which were chosen for maximum LOS and data collection purposes. The armor vehicles (5) were able to approach in any tactical formation at speeds they felt were realistic given the situation. Weapon simulator firing was done by both sides. Results are shown in table 9 for the infantry data and table 10 for the armor responses. An example of the spread of target ranges at time of recognition can be seen in figures 38 for infantry against armor targets and 39 and 40 for armor crews against infantry targets that were firing and nonfiring, respectively. Analysis of independent variable combinations and variables alone revealed they had no significant effect on detection, recognition, or engagement times or on the actual/estimated target speeds and ranges. Pairwise comparisons of actual or estimated ranges proved significant only for both buttoned and unbuttoned APC responses only (α = .05 level of significance). The average absolute difference in these two range values was 29 meters for buttoned crews and 42 meters for unbuttoned crews. APC crews overestimated target range in 57 percent of their recorded responses. Overall armor personnel target ranges were underestimated in 60 percent of the responses with an average absolute difference of 36 meters (see figures 41 and 42). The infantry underestimated target range in 65 percent of the responses with an average absolute difference of 37 meters between the estimated and actual ranges at time of target recognition.

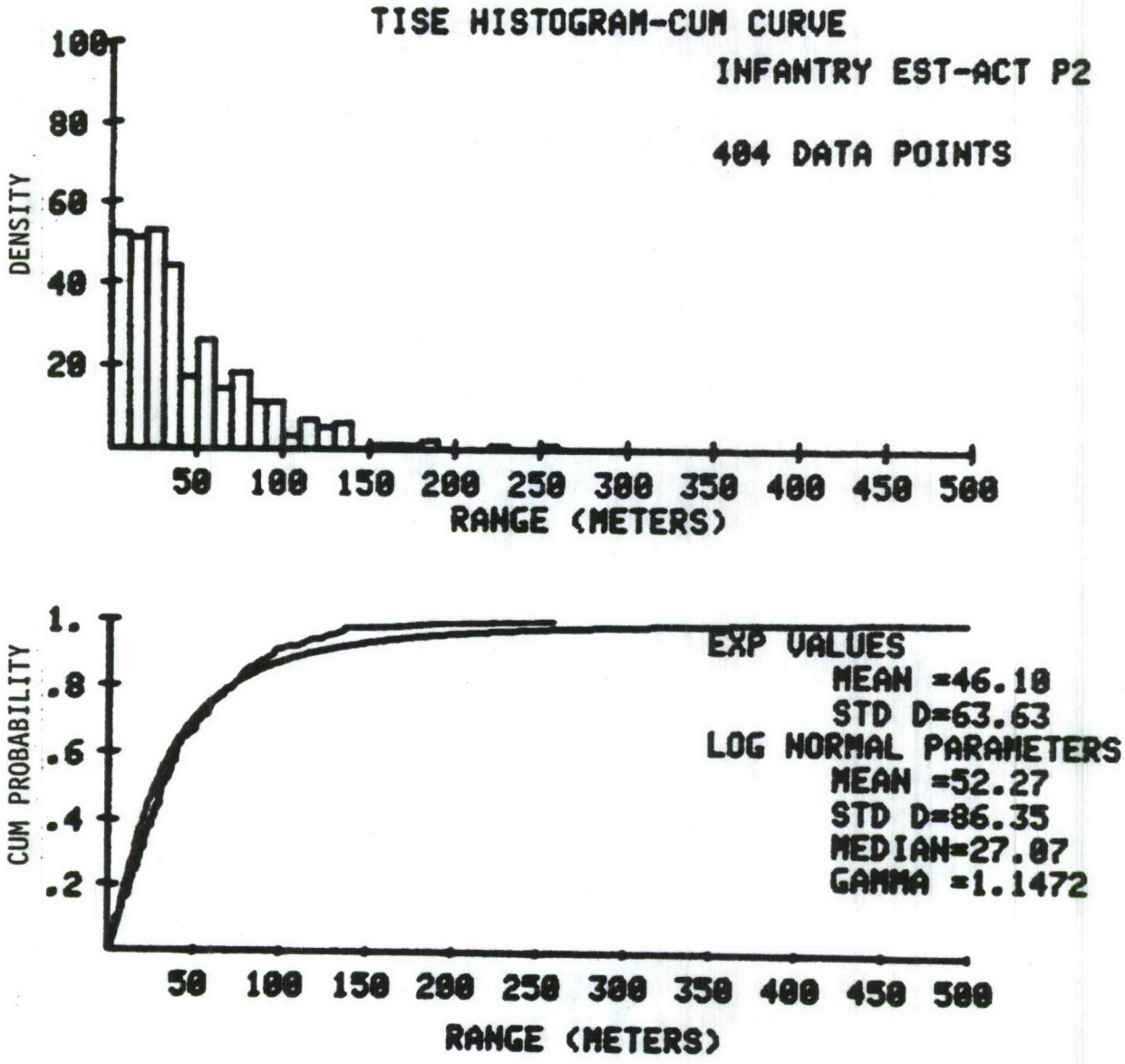

Figure 30. TISE part II, absolute difference between estimated and actual ranges at recognition by infantry

Table 7. Averages part III infantry responses individual matrix cells (time in seconds, range in meters)

			Armor	
			Buttoned	Unbuttoned
INFANTRY	SQUAD 1	time of target detection	307	266
		time of target recognition	308	274
		estimated target range	67	94
		actual target range	78	87
		no. correct recognitions	202	178
		no. incorrect recognitions	3	5
	SQUAD 2	time of target detection	276	275
		time of target recognition	278	273
		estimated target range	64	76
		actual target range	61	74
		no. correct recognitions	180	259
		no. incorrect recognitions	1	5

Table 8. Averages part III armor responses individual matrix cells (time in seconds, range in meters)

			Armor	
			Buttoned	Unbuttoned
INFANTRY	SQUAD 1	time of target detection	310	279
		time of target recognition	324	310
		estimated target range	82	65
		actual target range	63	69
		no. correct recognitions	59	69
		no. incorrect recognitions	0	0
	SQUAD 2	time of target detection	317	287
		time of target recognition	322	292
		estimated target range	58	69
		actual target range	32	59
		no. correct recognitions	41	99
		no. incorrect recognitions	0	0

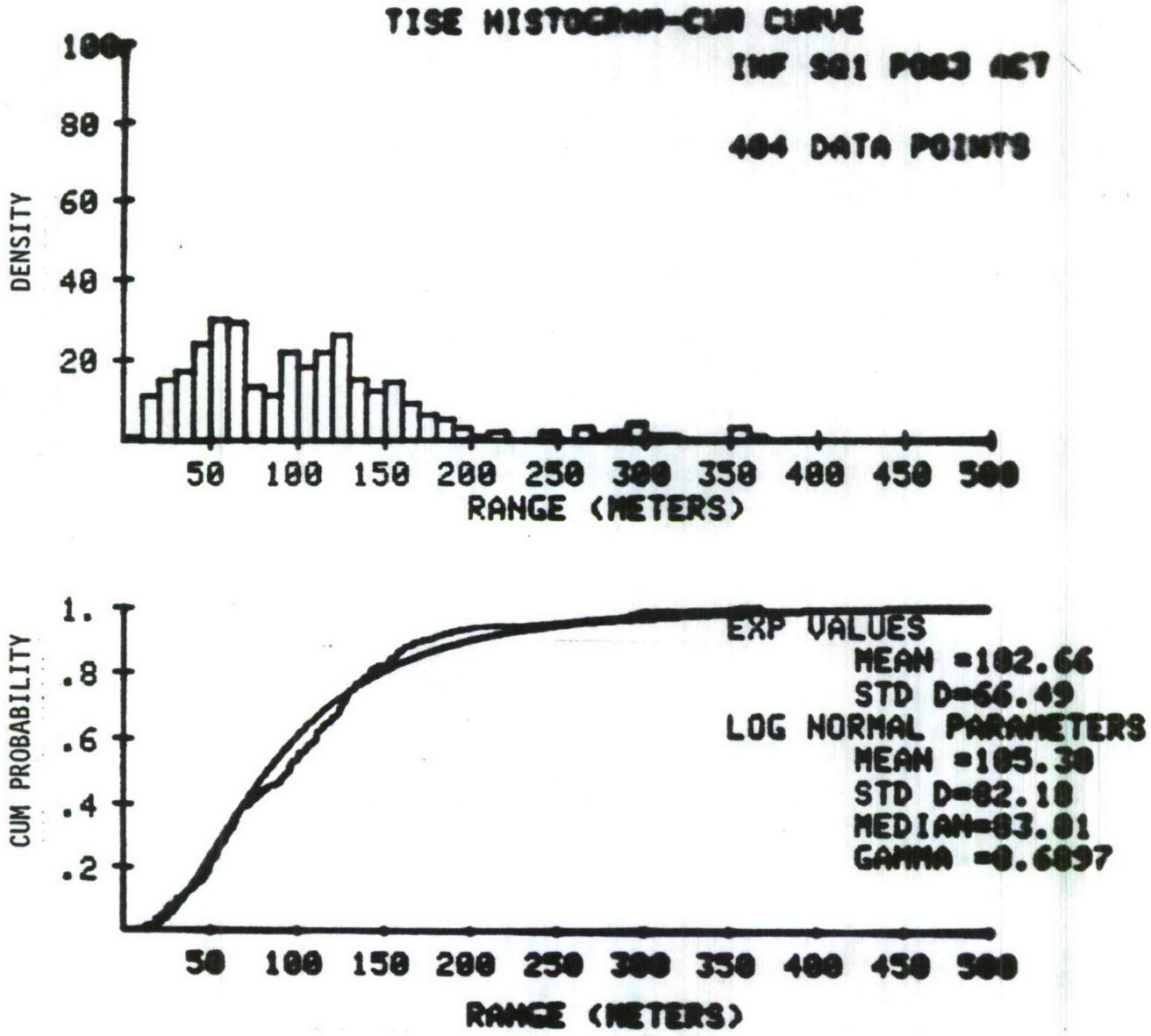

Figure 32. TISE part III, actual target ranges at recognition by infantry in squad 1

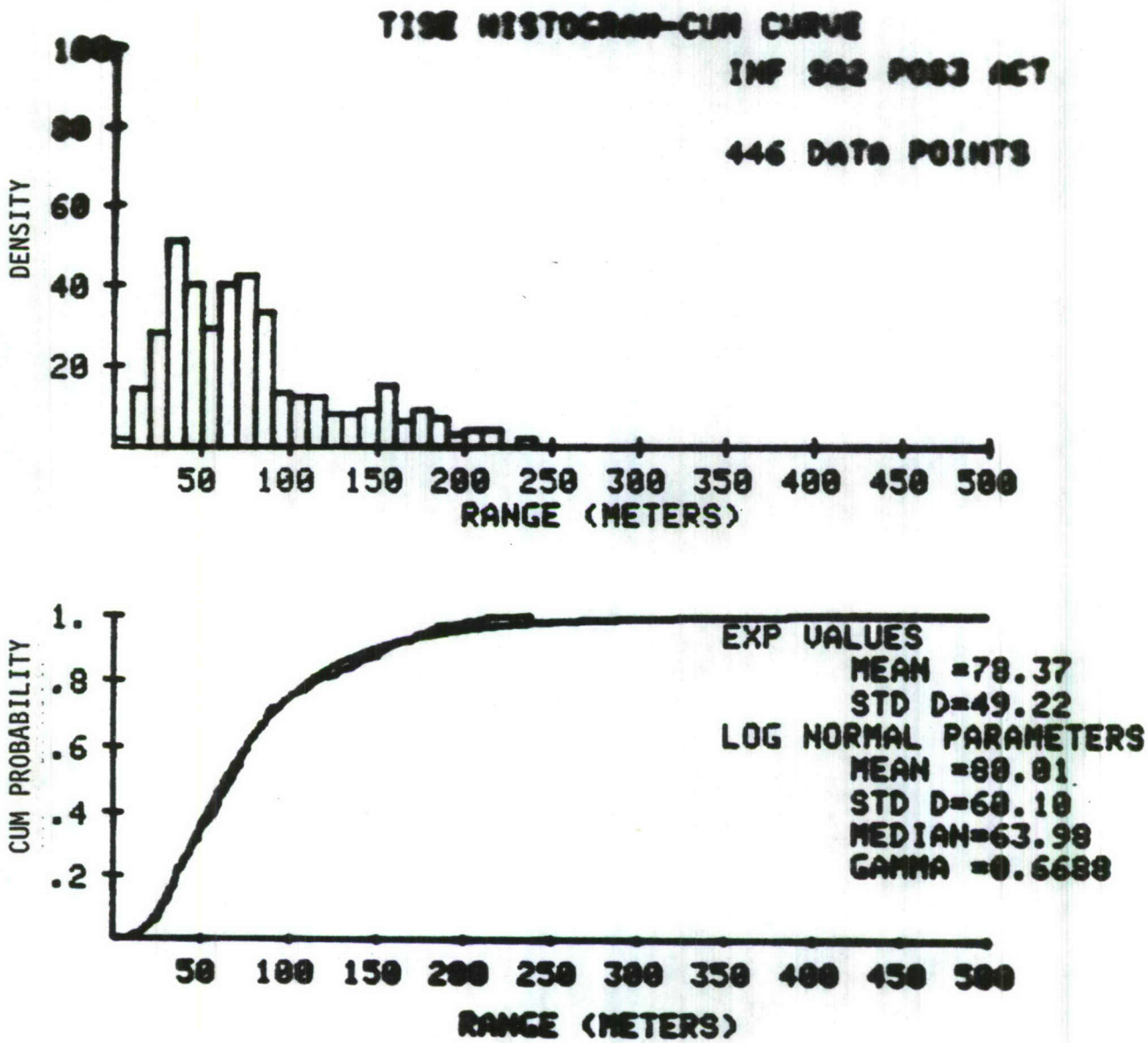

Figure 33. TISE part III, actual target ranges at recognition by infantry in squad 2

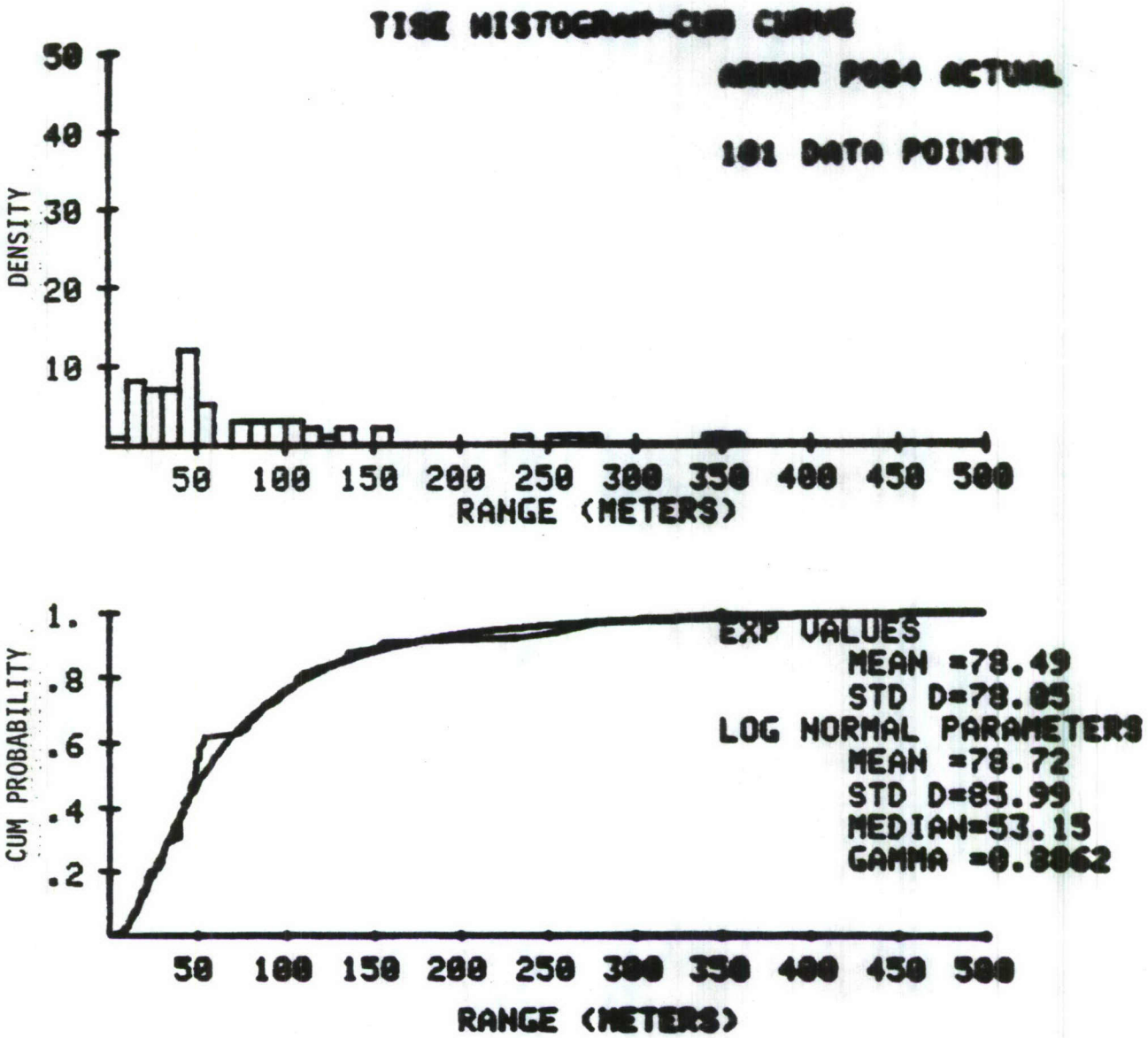

Figure 34. TISE part III, actual target ranges at recognition by buttoned armor

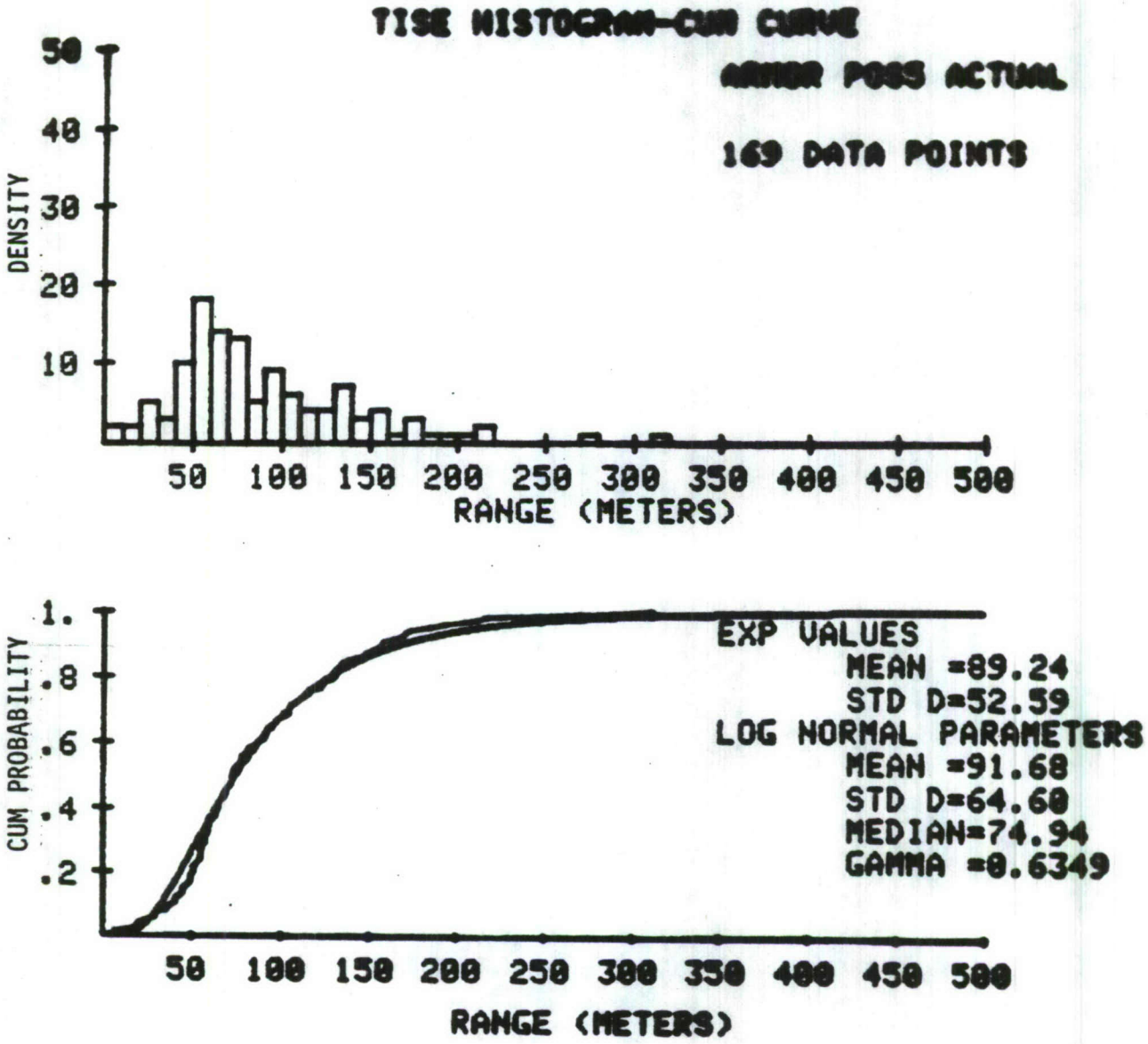

Figure 35. TISE part III, actual target ranges at recognition by unbuttoned armor

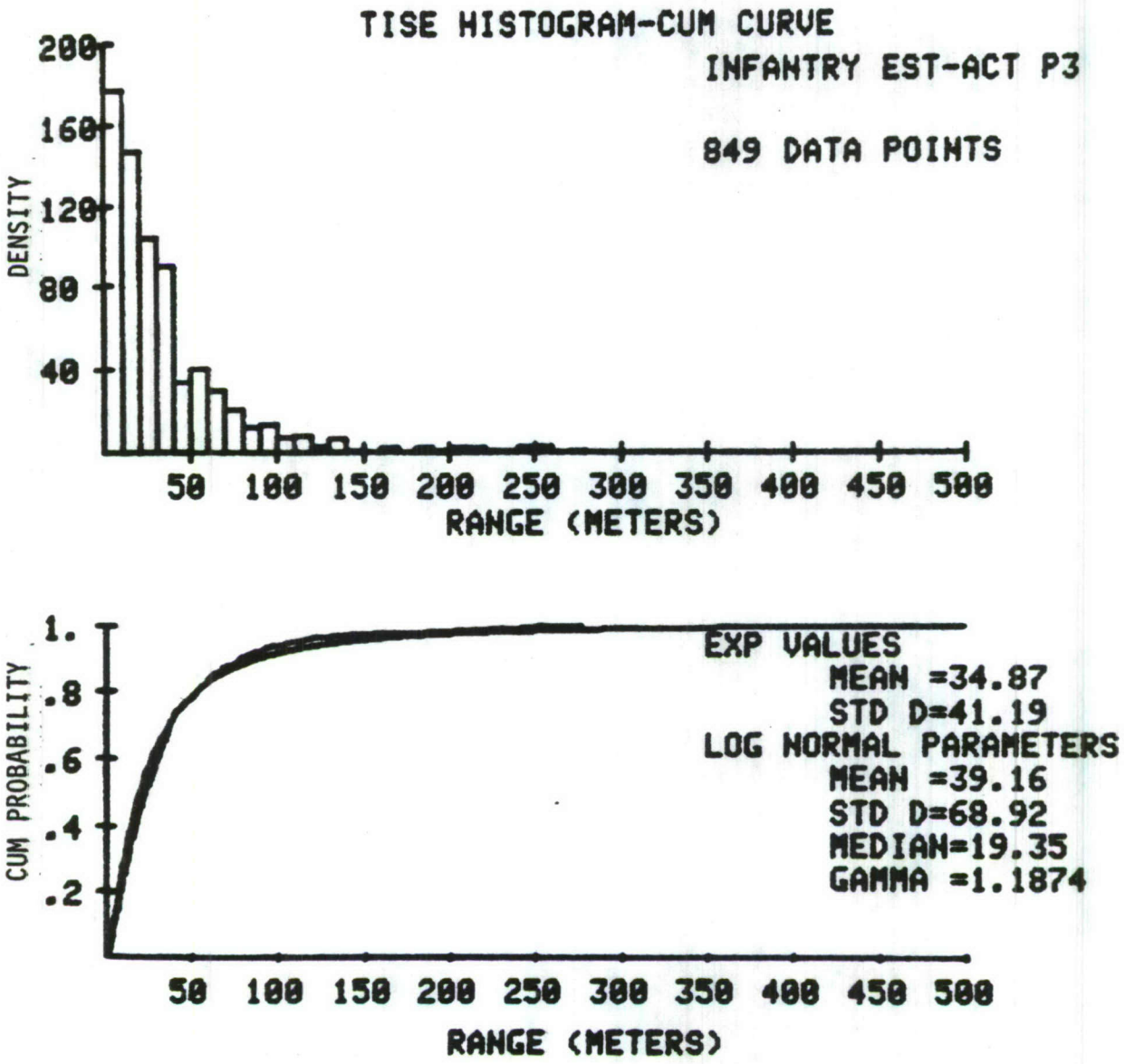

Figure 36. TISE part III, absolute difference between estimated and actual ranges at recognition by infantry

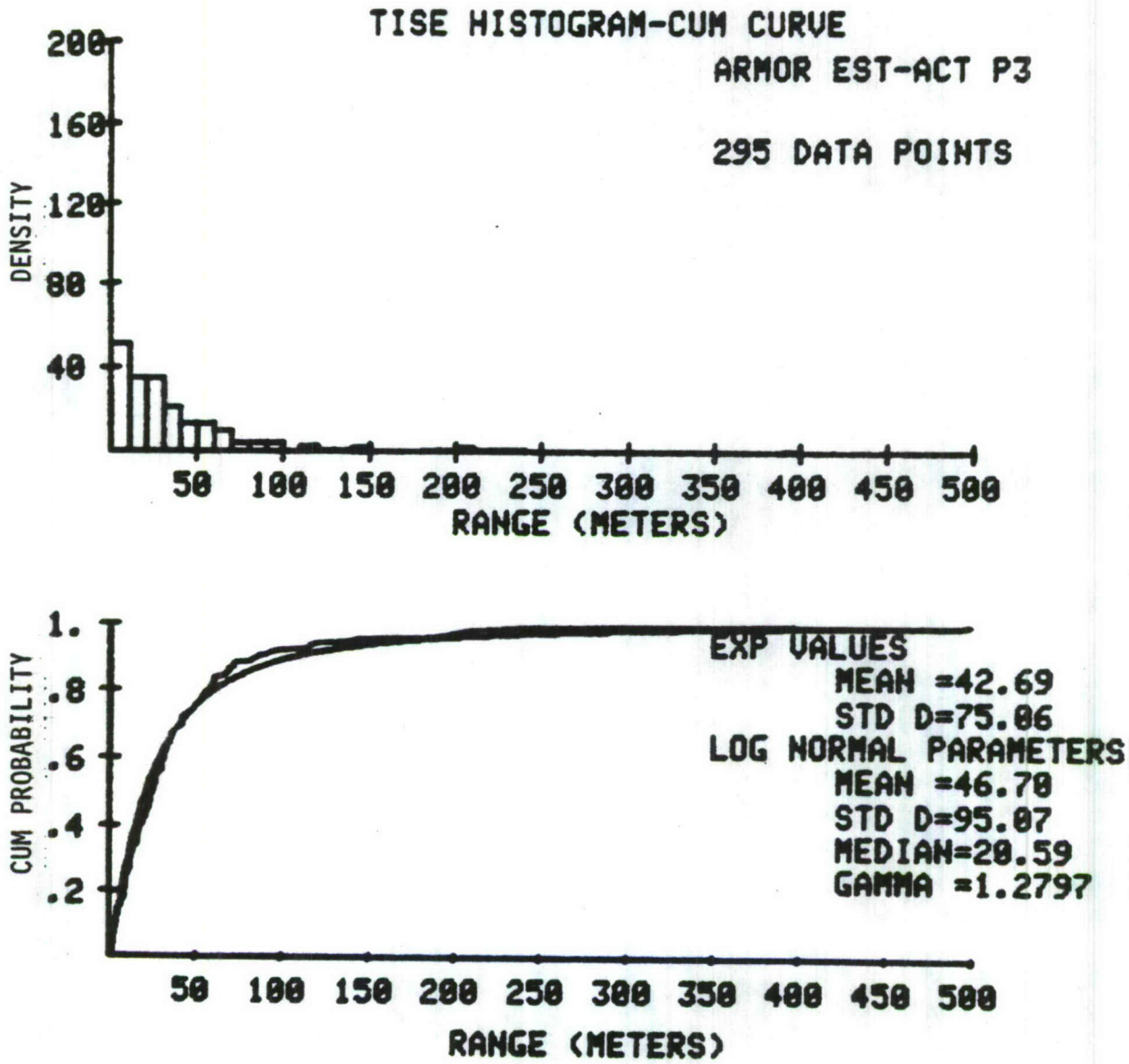

Figure 37. TISE part III, absolute difference between estimated and actual ranges at recognition by armor

Table 9. Averages part IV infantry responses individual matrix cells (time in seconds, range in meters)

			Armor	
			Buttoned	Unbuttoned
INFANTRY	Firing	time to target detection	121	121
		time to target recognition	123	124
		time to engagement	128	129
		estimated target range	84	89
		actual target range	97	115
		no. correct recognitions	94	84
		no. incorrect recognitions	1	3
	Nonfiring	time to target detection	98	97
		time to target recognition	99	99
		estimated target range	89	104
		actual target range	110	129
		no. correct recognitions	90	80
		no. incorrect recognitions	1	1

Table 10. Averages part IV armor responses individual matrix cells (time in seconds, range in meters)

			Armor	
			Buttoned	Unbuttoned
INFANTRY	Firing	time to target detection	119	110
		time to target recognition	122	113
		time to engagement	126	118
		estimated target range	66	63
		actual target range	91	73
		no. correct recognitions	12	16
		no. incorrect recognitions	10	15
	Nonfiring	time to target detection	111	98
		time to target recognition	114	100
		time to engagement	116	104
		estimated target range	660	81
		actual target range	57	90
		no. correct recognitions	8	8
		no. incorrect recognitions	5	13

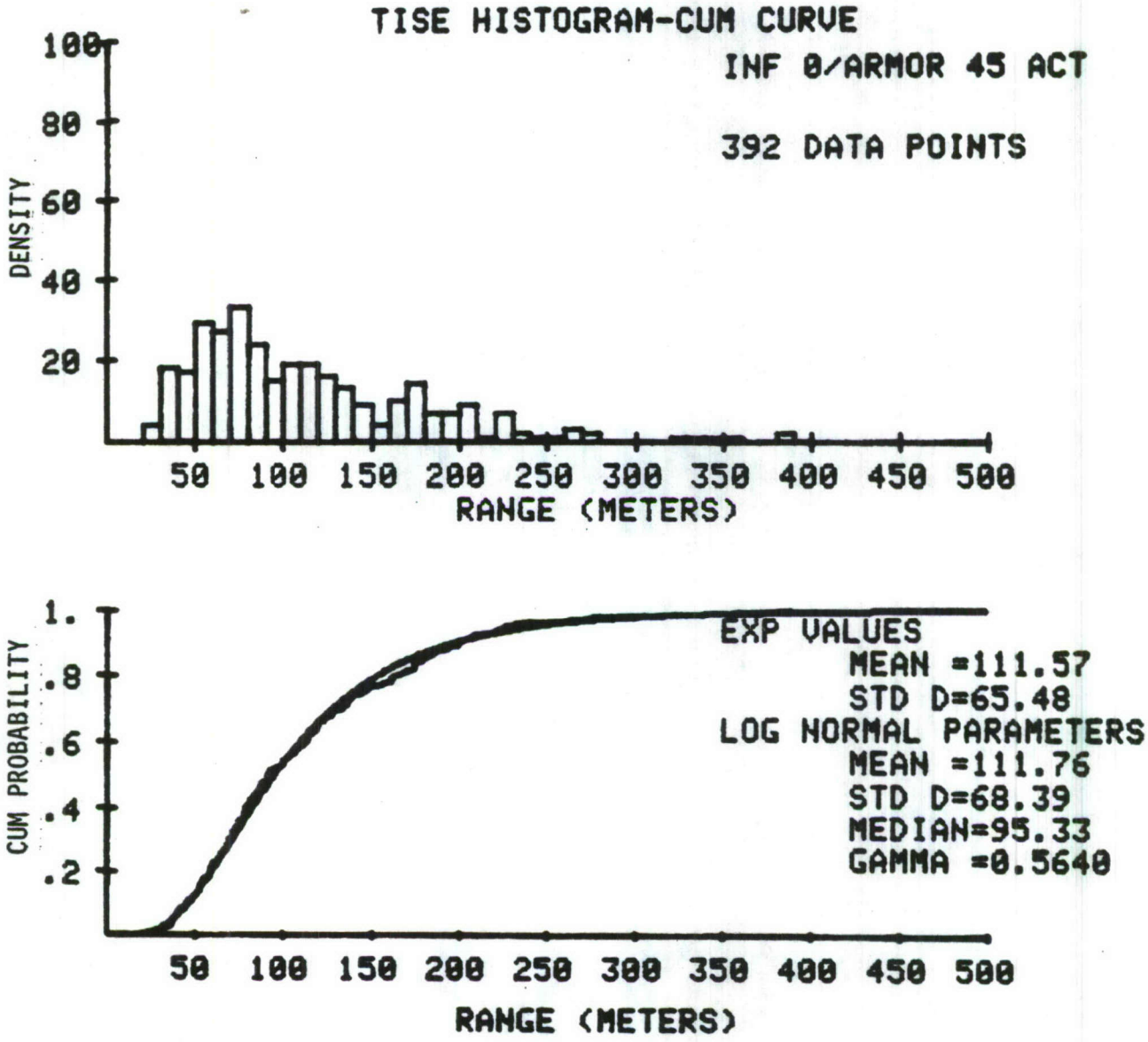

Figure 38. TISE part IV, actual target ranges at recognition by infantry

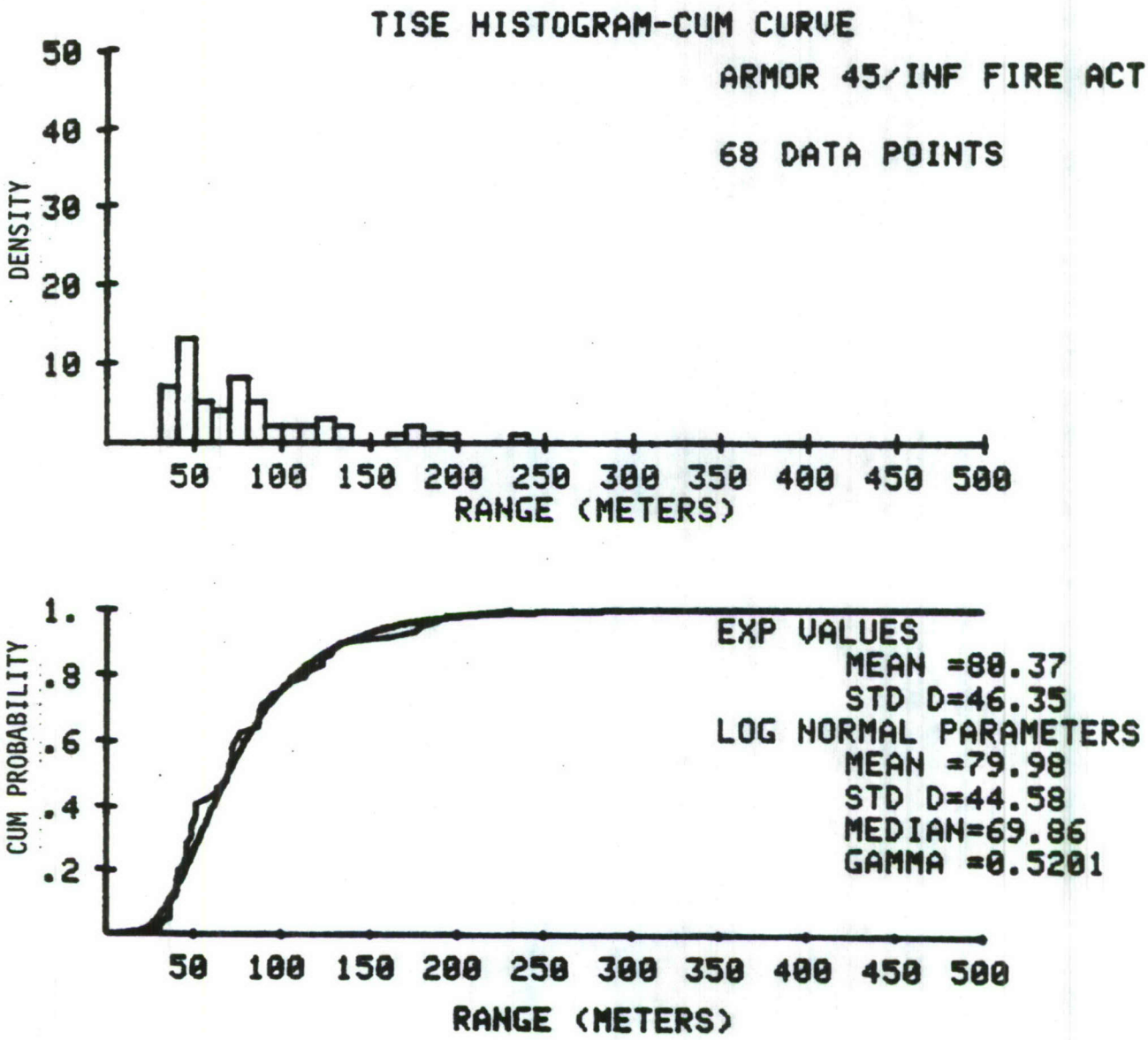

Figure 39. TISE part IV, actual target ranges at recognition of firing infantry by armor

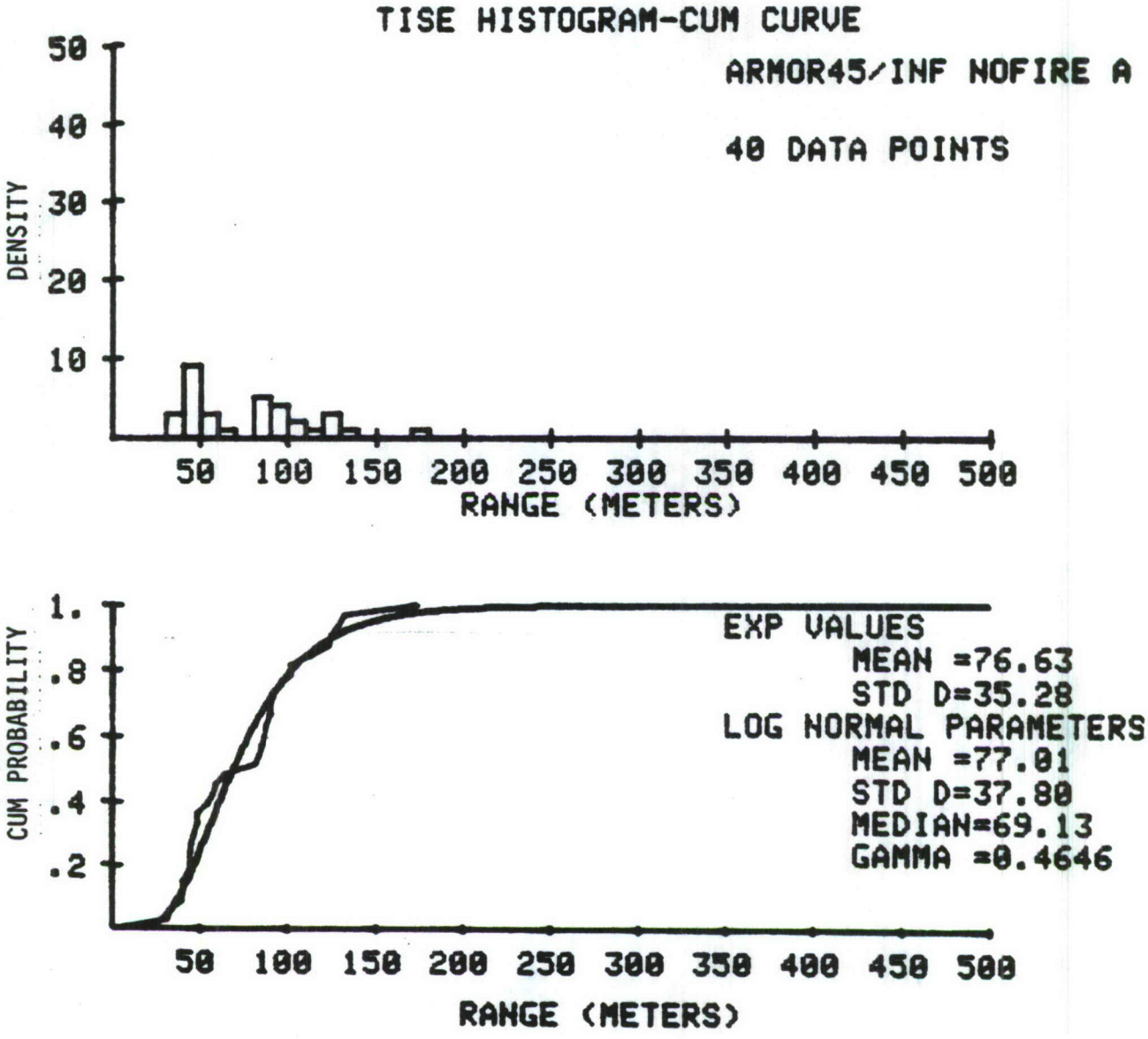

Figure 40. TISE part IV, actual target ranges at recognition of nonfiring infantry by armor

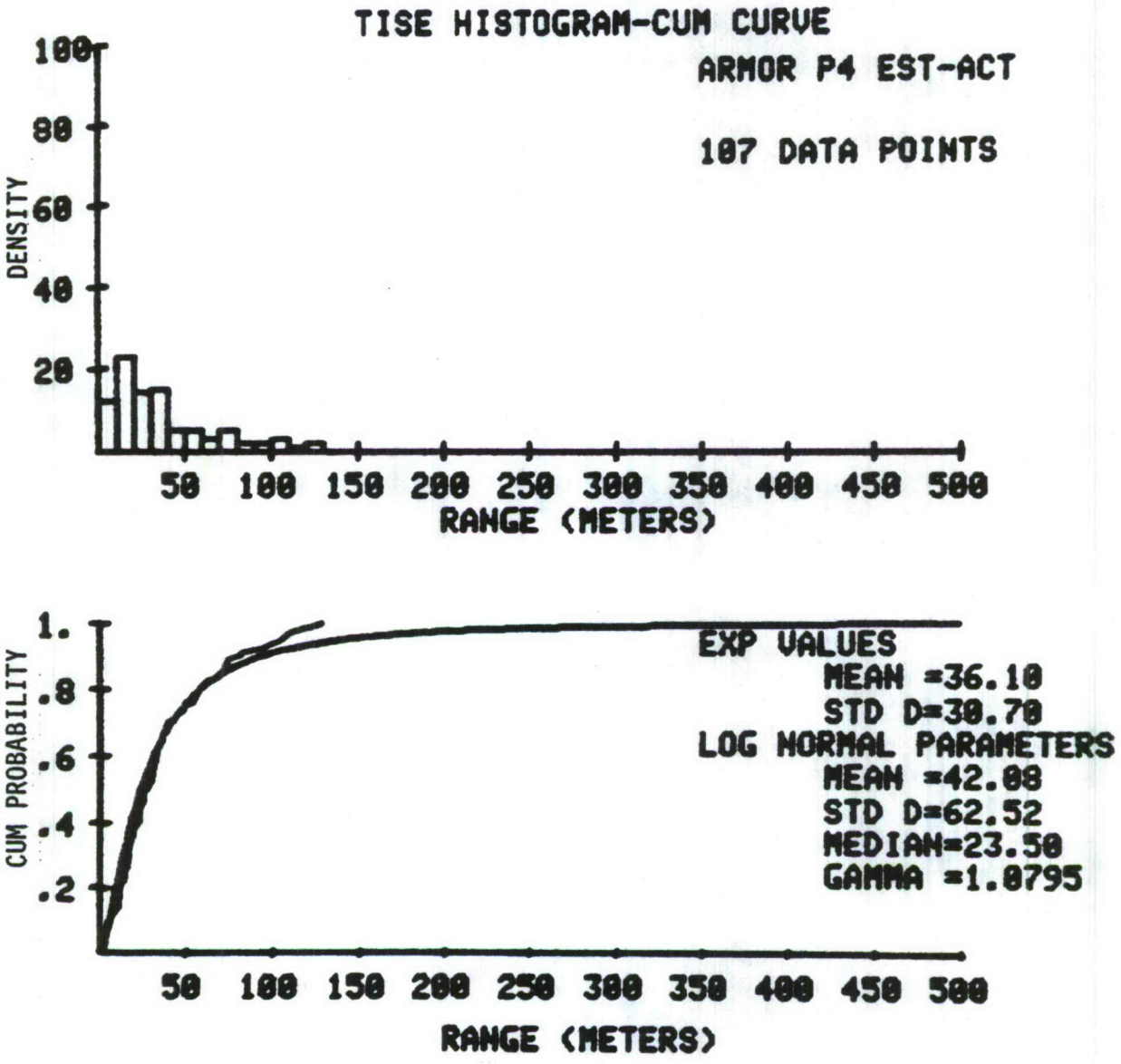

Figure 41. TISE part IV, absolute difference between estimated and actual target ranges at recognition by armor

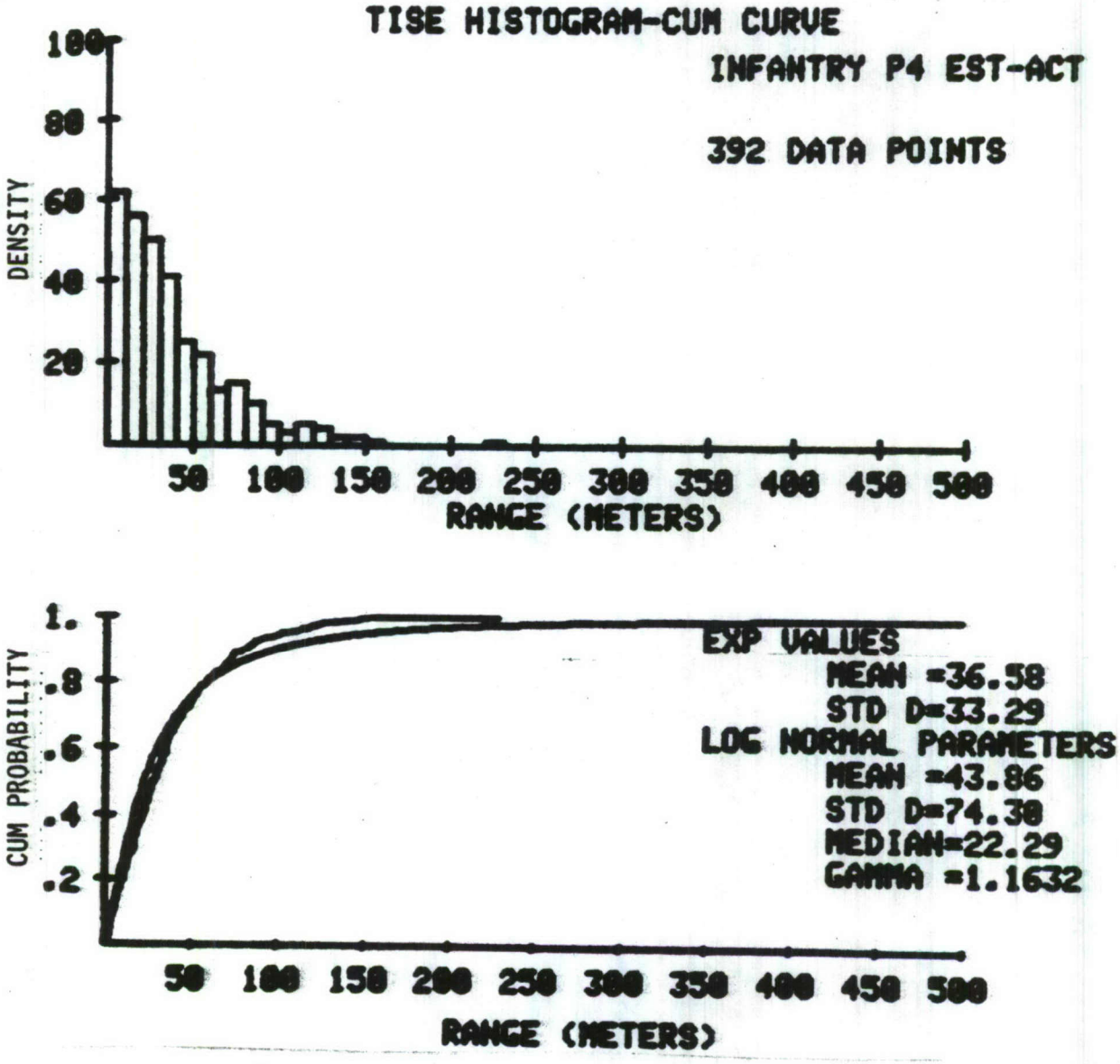

Figure 42. TISE part IV, absolute difference between estimated and actual target ranges at recognition by infantry

7. SUMMARY AND RECOMMENDATIONS. Of the seven independent variables tested, none had a significant effect on the dependent variables of detection, recognition, and engagement time or on the actual versus estimated target range and speed at time of recognition. Once targets were detected the process of recognition and engagement proceeded as it would have under more normal conditions. All players, armor and infantry, tended to underestimate target range in over 50 percent of the opportunities given. This may have been caused by the presence of the smoke or show a lack of training in estimation of target ranges. Average difference was approximately $\pm$ 20 meters. Visual cueing of targets by the flash of weapon fire had no significant effect on either the armor or infantry reaction times. The most reliable source of cueing was by sound. Infantry players detected armor targets before armor crews detected the infantry. Although this difference in time of detection/recognition was not statistically significant, these few seconds may make a significant difference in a real battle situation. In conclusion, it is recommended that testing of smoke be continued and expanded to include more tactically based usage of smoke and weapons. TISE has shown that by decreasing the recognition range and ability to identify targets smoke can be a useful tool in the type of situation that was simulated. With the increasing advances in technology, the effects of smoke on these new weapons and sighting systems need to be investigated thoroughly. Until it is known how these weapons are affected, it will remain difficult to develop effective tactics for the employment of smoke on the battlefield.

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